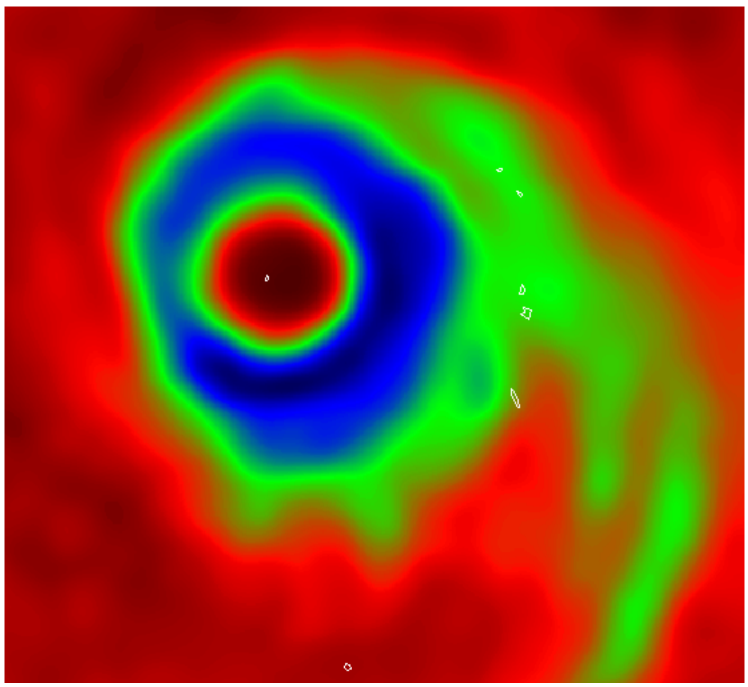
1998 ANNUAL TROPICAL CYCLONE REPORT



Microwave imagery of Typhoon Rex (06W) as it passed through the Bonin Islands, taken at 0800Z on 28 August. System intensity was estimated at 115 KTS.

JOINT TYPHOON WARNING CENTER
PEARL HARBOR, HAWAII

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14. ABSTRACT
The mission of the Joint Typhoon Warning Center is multi-faceted and includes: Continuous monitoring of all tropical weather activity in the Northern and Southern Hemispheres, from 180 degrees longitude westward to the east coast of Africa, and the prompt issuance of appropriate advisories and alerts when tropical cyclone development is anticipated.

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* TRANSFERRED DURING 1998

** ACTIVE DUTY TRAINING

EXECUTIVE SUMMARY

The 1998 tropical cyclone forecasting season was one of the most challenging in the 39-year history of the Joint Typhoon Warning Center (JTWC) due to the nature of the forecast season and the move of JTWC from Guam to Hawaii. In terms of forecast difficulty, the 1998 Western Pacific (WESTPAC) season was one of the toughest in the past two decades based upon the performance of the Climatology and Persistence (CLIPER) model (which provides us a baseline against which to measure our forecast skill). We also noted a number of anomalies in WESTPAC, many of which could be traced to the well-documented La Nina event that was on-going throughout the season. First, we had a very late start to the season. Our initial named storm, Tropical Storm Nichole, did not occur until 7 July. This was the latest occurrence for a named storm since JTWC has been keeping records (1959). We also had fewer tropical cyclones (tropical depressions and storms, typhoons and super-typhoons) than average with 27 in 1998 versus an average of approximately 31. The tropical cyclones that occurred also tended to be less intense than average. In 1998, we had 9 Tropical Depressions (TD), 9 Tropical Storms (TS), and 9 Typhoons (TY). We would expect an average (again, approximate) of 4 TD, 10 TS, and 18 TY. We definitely experienced a much higher percentage of TDs than usual and a significantly lower percentage of typhoons. The genesis areas for the storms was also substantially displaced to the west with a higher percentage of the storms forming in the South China Sea and fewer east of Guam than we normally expect. This point is amplified later in the report. Additionally, JTWC faced the daunting task of transferring operations from the Naval Pacific Meteorology and Oceanography Center West/Joint Typhoon Warning Center, Guam to the Naval Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center, Pearl Harbor, Hawaii in order to meet the requirements of Base Relocation and Closure legislation. In accomplishing the move, a number of challenges were overcome with outstanding results due to the dedication and devotion to duty of the airmen and sailors assigned to both commands. JTWC gradually shifted operations to Pearl Harbor over a two-month period (Nov-Dec, 98). This required JTWC to conduct split operations with a portion of forecasting watches occurring at Pearl Harbor and the rest in Guam. By 1 Jan 99, the move was complete and all watches were being stood in Hawaii. All the required equipment to support the tropical cyclone forecasting and Meteorological Satellite (METSAT) reconnaissance missions was transferred from Guam to Hawaii. Meanwhile, our METSAT personnel took on the added challenge of incorporating a new primary METSAT fixing system (NSDS-E) into their daily operations. On the Air Force side of JTWC, a new detachment was established under the Headquarters Pacific Air Forces Air Operations Squadron under the command of the JTWC Director. The majority of JTWC personnel reported directly to the new duty location in Pearl Harbor, Hawaii. As a result, JTWC experienced a 90 percent turnover in personnel starting in June, 1998. Again, the outstanding performance of JTWC personnel during an incredibly challenging season can not be overstated. What also can not be overstated is the significant contribution to JTWC operations from those in the research and support communities. Without the contributions of these unsung heroes, the challenging task of locating and forecasting the movement of tropical cyclones would be an impossible task. In the upcoming year, we pledge to leverage all available technology and science to continue to provide the best possible support to you, our customers.

FORWARD

The Annual Tropical Cyclone Report is prepared by the staff of the Naval Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center (JTWC), a joint Navy/Air Force organization. In 1998, the period covered by this report, JTWC operated under the command of the Commanding Officer, Naval Pacific Meteorology and Oceanography Center West (NAVPACMETOCCEN WEST)/Joint Typhoon Warning Center, Guam. In January of 1999, however, JTWC completed the transition from Guam to Pearl Harbor, Hawaii, as mandated by the 1995 Base Realignment And Closure Commission (BRAC), and now operates under the command of Commanding Officer, Naval Pacific Meteorology and Oceanography Center (NAVPACMETOCCEN)/Joint Typhoon Warning Center, Pearl Harbor, Hawaii. This move ends the nearly forty-year history of JTWC on Guam, which began on 01 May 1959 when the U.S. Commander in Chief Pacific (USCINCPAC) directed that a single tropical cyclone warning center be established for the North Western Pacific. No matter where JTWC is located, our customers will continue to receive the same dedicated support they have come to expect.

The mission of JTWC as directed by USCINCPAC Instruction 3140.1W (series) is multifaceted and includes:

1. Continuous monitoring of all tropical weather activity in the Northern and Southern Hemispheres, from 180 east longitude westward to the east coast of Africa, and the prompt issuance of appropriate advisories and alerts when tropical cyclone development is anticipated.

2. Issuance of warnings on all significant tropical cyclones in the above area of responsibility.

3. Determination of requirements for tropical cyclone reconnaissance and assignment of appropriate priorities.

4. Post-storm analysis of significant tropical cyclones occurring within the North Western Pacific and North Indian Oceans.

5. Cooperation with the Naval Research Laboratory, Monterey, California on evaluation of tropical cyclone models and forecast aids, and the development of new techniques to support forecast requirements.

Special thanks is extended to the following organizations for the timely operational support of the JTWC mission:

Alternate Joint Typhoon Warning Center (NAVPACMETOCCEN Pearl Harbor) Fleet Numerical Meteorology and Oceanography Center Air Force Weather Agency NOAA Satellite Data and Information Service 36th Communications Squadron Operations and Equipment Support Departments of both NAVPACMETOCCEN/JTWC Pearl Harbor and NAVPACMETOCCEN/JTWC Guam.

We also wish to thank the Office of Naval Research, Naval Research Laboratory, Monterey and Naval Postgraduate School for the tremendous research and development support. Of specific note, we would like to thank the following individuals:

Drs. Lester E. Carr III and Russell L. Elsberry for their continuing work on the Systematic and Integrated Approach to Tropical Cyclone Forecasting. Messrs. Jeff D. Hawkins, Chris S. Veldon, et. Al., for their continuing efforts to exploit remote sensing technologies. Mr. Charles R. "Buck" Sampson and Ms. Ann Schrader, et. Al., for their constant support and continued development of the Automated Tropical Cyclone Forecasting System.

Contents

Chapter 1
Operational Procedures

1.1 GENERAL

The Joint Typhoon Warning Center (JTWC) provides a variety of products and services to qualified organizations for the area of responsibility (AOR) described by USCINCPACINST 3140.1W. The following products are routinely issued by JTWC.

1.1.1 SIGNIFICANT TROPICAL WEATHER ADVISORY

Issued routinely once every 24 hours, or more frequently as needed, to describe all tropical disturbances and their potential for development into a significant tropical cyclone during the advisory period. Separate advisories are issued for the Western Pacific and the Indian Ocean.

1.1.2 TROPICAL CYCLONE FORMATION ALERT

Issued as conditions warrant and are intended to notify customers when a tropical disturbance is expected to develop into a significant tropical cyclone within 24 hours.

1.1.3 TROPICAL CYCLONE WARNING

Issued either at 6 hourly or 12 hourly intervals and provides forecasts of position, intensity, and wind distribution.

1.1.4 PROGNOSTIC REASONING MESSAGE

Issued in conjunction with tropical cyclone warnings in the North West Pacific (NWP). This message provides Meteorologists with the rationale for the intensity, movement and wind distribution contained in the JTWC warning.

1.1.5 PRODUCT CHANGES

The contents and availability of JTWC products and services are set forth in USCINCPACINST 3140.1W. Changes to USCINCPACINST 3140.1W are discussed and approved at the annual U.S. Pacific Command (PACOM) Tropical Cyclone Conference.

1.2 DATA SOURCES

1.2.1 COMPUTER PRODUCTS

Numerical and statistical guidance are provided to JTWC by Fleet Numerical Meteorology and Oceanography Center (FLENUMETOCCEN, or FNMOC) at Monterey, California. FNMOC also supplies JTWC with numerical analyses and prognoses from the Navy Operational Global Atmospheric Prediction System (NOGAPS) via the DOD NIPRNET network (Internet gateway). FNMOC furthermore, provides JTWC with numerical analyses and prognoses from the (U.S.) National Center for Environmental Prediction (NCEP), the European Centre for Medium-Range Weather Forecasts (ECMWF), and the Australian Meteorological Bureau.

1.2.2 CONVENTIONAL DATA

These data sets are comprised of land and ship surface observations, observations from commercial and military aircraft (AIREPS) recorded within six hours of synoptic times, and cloud-motion winds derived from satellite data. The data is computer plotted, and manually analyzed for the surface/gradient and 200-mb levels twice daily, at the 00Z and 12Z synoptic times.

1.2.3 SATELLITE RECONNAISSANCE

Meteorological satellite imagery is obtained from the Defense Meteorological Satellite Program (DMSP), National Oceanographic and Atmospheric Administration (NOAA), and other sources. Satellite reconnaissance is discussed further in Section 2.3, Satellite Reconnaissance Summary. In addition to visual, infrared and water vapor imagery, microwave data from DMSP and European Remote Sensing (ERS)-2 satellites provide additional information on tropical cyclone location and the distribution of low-level winds.

1.2.4 RADAR RECONNAISSANCE

When a well-defined TC moves within range of land-based radar sites, radar reports are invaluable for determination of position, movement, and, in the case of Doppler radar, storm structure and wind information. JTWC's use of radar reports during 1998 is described in Section 2.4, Radar Reconnaissance Summary.

1.2.5 AIRCRAFT RECONNAISSANCE

No aircraft fixes were available in 1998.

1.2.6 DRIFTING METEOROLOGICAL BUOYS

In 1998, 30 drifting buoys were deployed in the NWP by Air National Guard C-130 aircraft under the auspices of NAVOCEANO in support of JTWC. This buoy deployment is part of a continuing Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) Integrated Drifting Buoy Plan support effort implemented to meet CINCPACFLT tropical cyclone warning support requirements.

Of the 30 buoys, 24 were Compact Meteorological and Oceanographic Drifters (CMOD) with temperature and pressure sensors and six were Wind Speed and Direction (WSD) buoys which measured windspeed and direction, temperature and pressure. Both type buoys were used in two deployments; one in June and another in September. The purpose of the two deployments was to overlap the expected three-month life-span of the CMOD buoys to provide continuous buoy coverage during the peak of the NWP Ocean tropical cyclone season.

1.2.7 AUTOMATED METEOROLOGICAL OBSERVING STATION (AMOS)

Through a cooperative effort between COMNAVMETOCCOM, the Department of the Interior, and NOAA/NWS to increase data availability for tropical analysis and forecasting, a network of AMOS stations has been installed in Micronesia. Table 1-1 provides a summary of the current AMOS configuration.

NWS Pacific Region (NWSPR) made a decision in mid FY 98 to discontinue deployment and maintenance of Coastal-Marine Automated Network (C-MAN) equipment procured from the NWS National Data Buoy Center for AMOS. This decision was based on the fact that the existing equipment was outdated, required extensive retrofit/refurbishing, and was too hardware and labor intensive to continue support for operations in remote Pacific island environments.

The NWSPR has had many years of experience with the installation and maintenance of Handar manufactured meteorological and tidal stations, which, although they do not provide the redundancy in sensors and communications capability, do function extremely well in remote tropical island environments.

Two AMOS sites, Kosrae and Enewetak were converted from C-MAN to Handar equipment in 1998. NWSPR plans for 1999 are to convert 3 AMOS sites (Pagan, Ngulu and Ulithi) to Handar and install a new AMOS site at Sorol Atoll, Federated States of Micronesia, if resources permit. Lack of affordable transportation to these remote locations has been and continues to be the limiting factor in a more speedy installation effort.

1.3 TELECOMMUNICATIONS

Primary telecommunications support for the Naval Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center (NPMOC/JTWC) is provided by the Naval Computer and Telecommunications Station (NCTS).

1.3.1 AUTOMATED DIGITAL NETWORK (AUTODIN)

AUTODIN is the primary medium for disseminating JTWC products to DOD customers. AUTODIN messages are also relayed via commercial telecommunications routes for delivery to non-DOD users.

1.3.2 AUTOMATED WEATHER NETWORK (AWN)

The AWN provides DOD and WMO weather data for in-house analysis and is also used to transmit JTWC products to DOD and U. S. government users. JTWC's AWN station identifier is PGTW.

1.3.3 AUTOMATED WEATHER DISTRIBUTION SYSTEM (AWDS)

The AWDS consists of two dual-monitor workstations which communicate with a UNIX based communications/data server via a private Local Area Network (LAN). The server's data connectivity is provided by two

Table 1-1 Automated Meteorological Observing Station Summary					
Station ID	Site Name	Site Lo	cation	Installed	Status
REPUBLIC OF THE MARSHALL ISLANDS					
1. 91442	Ebon Atoll	4.60N,	168.70E	07/96	Partially functional
2. 91251	Enewetak Atoll	11.43N,	162.35E	11/89	Handar installed 1998
3. 91374	Maloelap Atoll	8.70N,	171.20E	08/96	Fully functional
4. 91377	Mili Atoll	6.10N,	172.10E	12/90	Partially functional
5. 91365	Ujae Atoll	8.93N,	165.75E	11/89	Not functioning (Destroyed by TY Gay, 1992)
FEDERATED STATES OF MICRONESIA					
6. 91411	Ngulu Atoll	8.30N,	137.50E	10/95	Partially functional (Handar planned for 1999)
7. 91343	Oroluk	7.63N,	155.16E	07/91	Partially functional
8. 91352	Pingelap	6.21N,	160.70E	09/91	Partially functional
9. 91355	Kosrae	5.36N,	162.96E	09/90	Handar 1998
10. 91338	Satawan	5.28N,	153.65E	03/93	Not functional
11. 91204	Ulithi	9.90N,	139.70E	11/95	Partially functional (Handar planned for 1999)
12. 91328	Ulul Atoll	8.60N,	149.67E	03/92	Fully functional
COMMONWEALTH OF THE N. MARIANA ISLANDS					
13. 91222	Pagan Island	18.13N,	145.77E	06/90	Not functional (Handar planned for 1999)
14.	Sorol Atoll				Planned 1999

dedicated long-haul data circuits. The AWDS provides JTWC with additional transmit and receive access to alphanumeric AWN data at Tinker AFB using a dedicated 9.6 kb/sec circuit. Access to satellite imagery and computer graphics from Air Force Weather Agency (AFWA) is provided by another dedicated 9.6 kb/sec circuit. The current configuration of AWDS was upgraded in 1996 to include improved workstation performance, and integration into NPMOCW's LAN backbone, this has access to the Defense Information Systems Network's (DISN), Non-secure Internet Protocol (IP) Router Network's (NIPRNET) Wide Area Network (WAN). The LAN and WAN connectivity allow JTWC to send and receive products among other AWDS. This system will be installed during 1999 at Pearl Harbor.

1.3.4 DEFENSE SWITCHED NETWORK (DSN)

DSN is a worldwide, general purpose, switched telecommunications network for the DOD. The network provides a voice and data link by which JTWC communicates TC information with DOD installations and civilian agencies. JTWC utilizes DSN for all switched voice and data. The telephone numbers for JTWC are DSN 474-2320 or Commercial (808) 474-2320.

1.3.5 NIPRNET/SIPRNET

The DOD unclassified TCP/IP based NIPRNET network and the classified Secret IP Router Network (SIPRNET) are routinely utilized to obtain meteorological and operational information that is vital to

JTWC. These networks are further used to disseminate tropical cyclone information. JTWC's unclassified NIPRNET web site address is http://www.npmoc.navy.mil./jtwc.html

1.3.6 TELEPHONE FACSIMILE (TELEFAX)

TELEFAX provides the capability to rapidly scan and transmit, or receive, documents over commercial telephone lines or DSN.

1.4 DATA DISPLAYS

1.4.1 AUTOMATED TROPICAL CYCLONE FORECAST (ATCF) SYSTEM

The UNIX based ATCF is the paramount system used by the Typhoon Duty Officer (TDO) in the preparation and dissemination of JTWC's products. Developed to automate the mundane and labor intensive tasks associated with tropical cyclone forecasting, ATCF can automatically display meteorological satellite fixes, working and objective best tracks, forecasts of track, intensity, and wind distribution, information from computer generated forecast aids, and products from other agencies. It also computes the statistics used and disseminated by JTWC.

1.4.2 NAVAL SATELLITE DISPLAY SYSTEM ENHANCED (NSDS-E)

NSDS-E is an implementation of the Terascan 3.0 software package developed by Seaspace. JTWC runs this package on three Sun workstations. It is used to process high resolution satellite imagery.

1.5 ANALYSES

The JTWC TDO routinely performs manual streamline analyses of composite surface/gradient-level (3000 ft (914 m)) and upper-tropospheric (centered on the 200-mb level) data for 00Z and 12Z daily. Computer analyses are conducted for other levels. Additional analyses and/or data plotting are conducted during periods of significant or unusual activity at intermediate synoptic times. Special products such as station-time plot diagrams, time-height cross-section charts and pressure-change charts are produced during these periods.

1.6 FORECAST PROCEDURES

This section discusses the Systematic and Integrated Approach to TC Track Forecasting by Carr and Elsberry (1994), referred to hereafter as the "Systematic Approach" and then provides JTWC's basic approach to track, intensity and wind radii forecasting.

1.6.1 THE SYSTEMATIC APPROACH

JTWC began applying the Systematic Approach (Figure 1-1) in 1994. The basic premise of this approach is that forecasters can improve upon dynamical track forecasts [guidance] generated by numerical models and other objective guidance if the forecasters are equipped with:

1) A meteorological knowledge base of conceptual models that organizes a wide array of scenarios into a relatively few recurring, dynamically-related situations; and

2) a knowledge base of numerical model tropical cyclone forecast traits and objective-aid traits within the different recurring situations that are organized around the meteorological knowledge base.

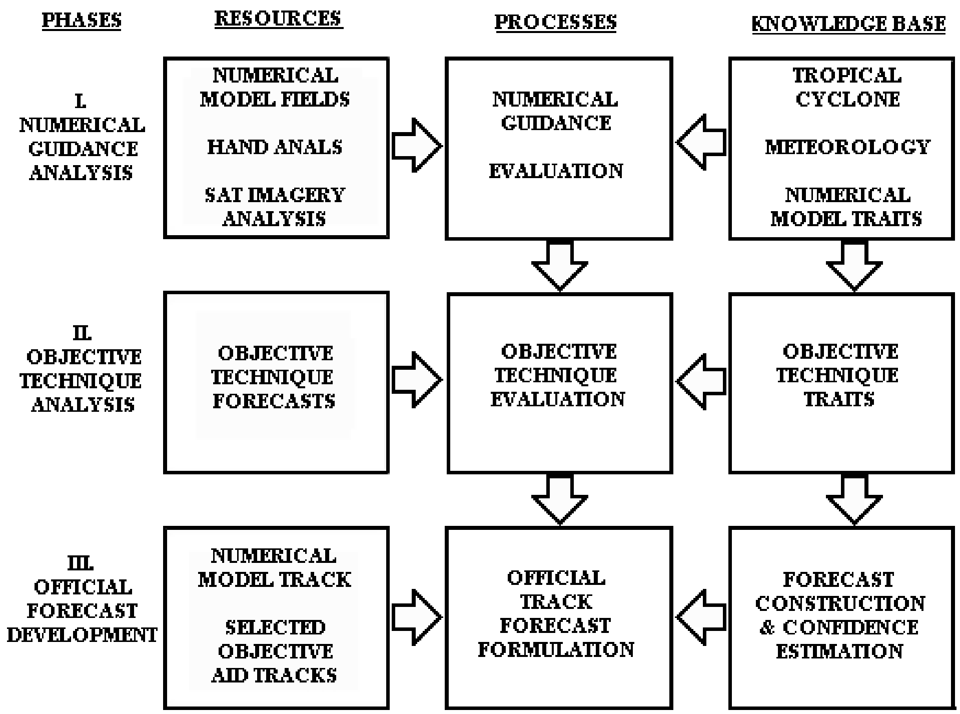


Figure 1-1. Systematic Approach Flowchart

1.6.1.1 General Concepts

Track, intensity, and size components of a TC forecast are dynamically interdependent.

1) TC motion affects intensity and how a TC intensifies can affect its motion.

2) TC size affects propagation relative to environmental steering. A large TC may significantly modify its environment. Thus, the present size of a TC and any subsequent changes in size can affect motion.

3) TC size may affect intensity indirectly through changes induced on TC motion.

1.6.1.2 Key Motion Concepts

TC motion results from a variety of causes.

1) Environmental Steering - To a first approximation, the TC vortex is advected by the winds of the large-scale environmental flow (i.e., the TC moves as a "cork in the stream").

2) TC Propagation - The motion of TCs usually departs in a minor, but not insignificant way from the large scale environmental steering vector.

3) TC-Environment Interaction - In certain situations, the circulation of the TC interacts with the environment in such a way as to significantly alter the structure of the environment, and thus modifies the steering vector that is the first-order effect on the motion of the TC.

1.6.1.3 Knowledge Base Framework

1.6.1.3.1 Environment Structure

Structure is classified in terms of a large-scale synoptic PATTERN and two or more synoptic REGIONS within the pattern that tend to produce characteristic directions and speeds of steering flow for a TC located therein. Five patterns with ten associated regions are recognized by the Systematic Approach. JTWC notes that not all TCs fit "neatly" into these patterns/regions at all times and that hybrids and transitions between patterns occur. These patterns/regions are briefly described below.

1.6.1.3.1.1 Patterns

There are five primary patterns:

1) STANDARD (S) (Figure 1-2)

- **1)** Most frequently occurring pattern in the NWP; and
- **2)** key feature is roughly zonally-oriented Subtropical Ridge (STR) anticyclones.

2) POLEWARD (P) (Figure 1-3)

- **1)** Second highest frequency of occurrence in the NWP;
- **2)** key feature is a ridge (anticyclone) that extends from the STR deep into the tropics and interrupts the tropical easterlies;
- **3)** usually has SW-to-NE axis orientation; and,
- **4)** usually produces strong poleward steering on its west and poleward side.

3) GYRE (G) (Figure 1-4)

- **1)** Only occurs during June-November period;

2) key feature is a particularly large and deep monsoonal circulation (thus, "monsoon gyre"); and,

3) usually situated between a zonally-oriented STR anticyclone to the NW and a meridionally-oriented anticyclone on its eastern periphery.

4) MULTIPLE (M) (Figure 1-5)

1) Key feature is more than one TC with a large break in the STR in the vicinity of the two TCs;

2) the TCs are oriented approximately east-west (i.e., zonally-oriented TCs);

3) the TCs must be far enough apart to preclude significant mutual advection, but close enough to preclude the development of ridging between them (typically greater than 10, but less than about 25);

4) the average latitude of the two TCs must be sufficiently close to the latitude of the STR axis (no more than about 10 equatorward or 5 poleward) so that regions of poleward/equatorward flow are established, which affect TC motion and intensification; and,

5) there are three subsets of the "M" pattern which describe varying degrees of interaction between the two cyclones.

5) HIGH AMPLITUDE (HA) (Figure 1-6) A newly identified pattern for the Southern Hemisphere. The key feature is a mid-latitude trough which penetrates very deeply into the tropics, almost to the equator. A combination of this trough and the subtropical ridge circulation to its east can produce long, southeastward oriented tracks. The ridge circulation to the west completes the pattern, by defining "Ridge Equatorward" and "Ridge Poleward" regions. A small area of "Equatorward Westerlies" is also defined.

1.6.1.3.1.2 Regions

There are ten primary regions associated with the four patterns:

EQUATORIAL WESTERLIES (EW) - The area of equatorial westerlies equatorward of the monsoon trough axis.

DOMINANT RIDGE (DR) - The area of tropical easterlies equatorward of the STR axis, except near any break in the STR.

WEAKENED RIDGE (WR) - The area of weaker southeasterly winds in the vicinity of a break in the STR.

MIDLATITUDE WESTERLIES (MW) - The area of eastward and poleward steering extending east from a break in the STR.

POLEWARD-ORIENTED (PO) - The area of poleward steering west of the ridge feature in the "P" and "G" Patterns

POLEWARD FLOW (PF) - Created in the vicinity of the eastern TC of a "M" Pattern as a result of the gradient between the western TC and the STR circulation to the east.

RIDGE POLEWARD (RP) - The poleward flow region of the HA pattern, where steering is provided by the western side of the anti-cyclone.

RIDGE EQUATORWARD (RE) - The equatorward flow region of the HA pattern, where steering is provided by the eastern side of the anti-cyclone.

TROUGH POLEWARD (TP) - The very long poleward flow region of the HA pattern, where steering is provided by the deeply penetrating mid-latitude trough.

EQUATORWARD FLOW (EF) - Created in the region of the western TC of a ”M” Pattern as a result of the gradient between the eastern TC and the STR circulation to the west.

1.6.1.3.1.3 Nomenclature

JTWC makes routine use of the aforementioned Patterns and Regions of the Systematic Approach. In order to quickly transcribe this information, a short-hand contraction standard has developed. By utilizing the one-letter contraction of a pattern and the two-letter contraction of an associated region (e.g., S/DR), an effective method of quickly and accurately describing Systematic Approach concepts in writing exists.

1.6.1.3.2 TC Structure

TC structure consists of an INTENSITY that is based on the maximum wind speed near the center of the TC, and a SIZE that is based on some measure of the extent of the cyclonic wind component in the lower atmosphere. TC intensity is related to steering level and TC size is related to propagation and environment modification.

1.6.1.3.3 Transitional Mechanisms

These mechanisms act to change the structure of the environment (pattern/region) and fall into two categories:

1) TC-Environment Transformations. The TC and the environment may interact, resulting in a change in environmental structure (pattern/region) and thus the direction/speed of the associated steering flow. In addition, TC-environment transformations may result in a change to TC structure. Listed below are recognized TC-environment transformations:

- Beta Effect Propagation
- Vertical Wind Shear
- Ridge Modification by TC
- Monsoon Gyre-TC Interaction
- TC Interaction (Direct (DTI), Semi-direct (STI), and Indirect (ITI)) (Figure 1-7)

2) Environmental Effects. These also result in changes to the structure of the environment (pattern/region) surrounding the TC, but do not depend on, are or largely independent of, the presence of the TC. Recognized environmental effects are listed below:

- Advection by Environment

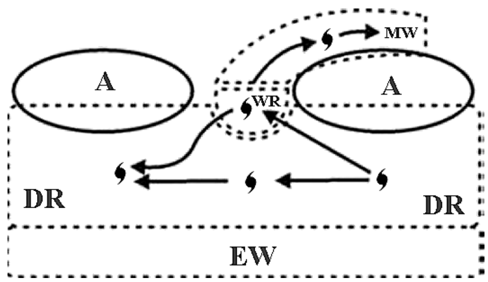


Figure 1-2. Standard Pattern

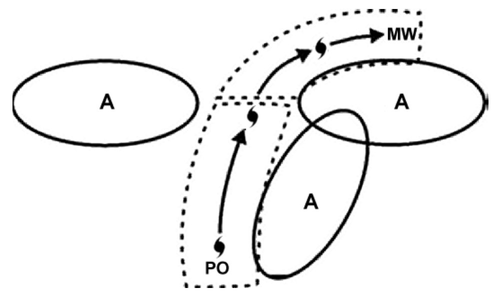


Figure 1-3. Poleward Pattern

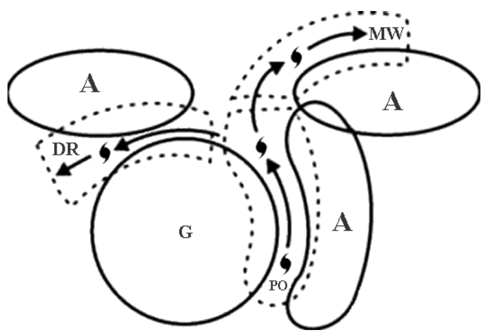


Figure 1-4. Gyre Pattern

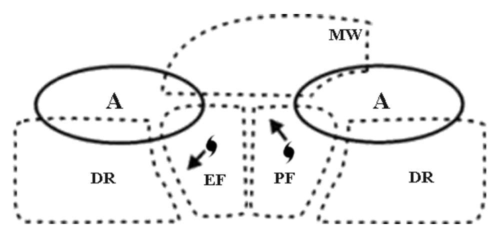


Figure 1-5. Multiple TC Pattern

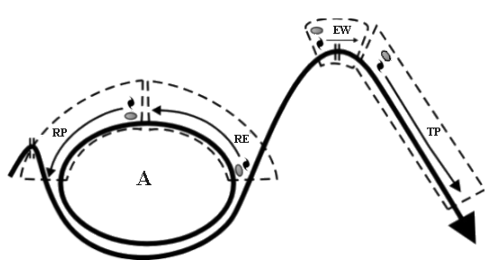


Figure 1-6 High Amplitude Pattern

LEGEND FOR FIGURES:

➔	= CHARACTERISTIC TC TRACK	PF	= POLEWARD FLOW
- -	= REGIONAL BOUNDARY	RP	= RIDGE POLEWARD
DR	= DOMINANT RIDGE	RE	= RIDGE EQUATORWARD
A	= ANTICYCLONE	PO	= POLEWARD ORIENTATED
MW	= MIDLATITUDE WESTERLIES	EW	= EQUATORIAL WESTERLIES
G	= GYRE	TP	= TROUGH POLEWARD
WR	= WEAKENED RIDGE	EF	= EQUATORIAL

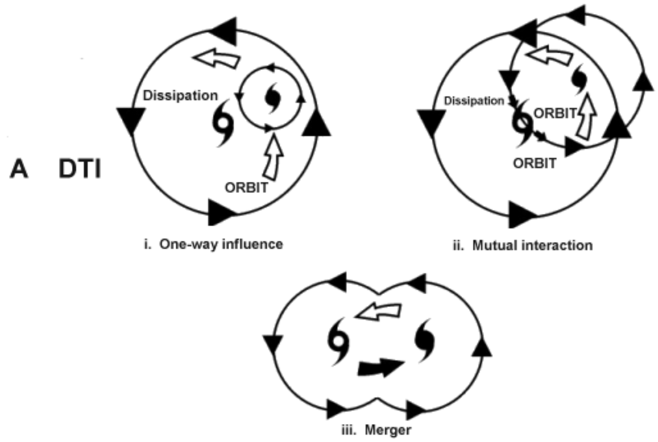


Figure 1-7a. Tropical Cyclone Interaction: (a) Direct TC Interaction (DTI) is composed of three types - (i) one way influence, (ii) mutual interaction, and (iii) merger.

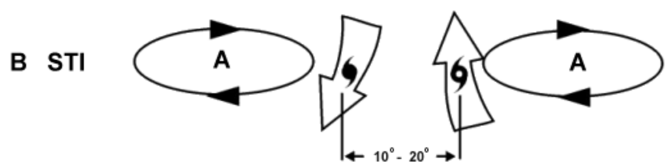


Figure 1-7b. Tropical Cyclone Interaction: Semi-Direct TC Interaction (STI).

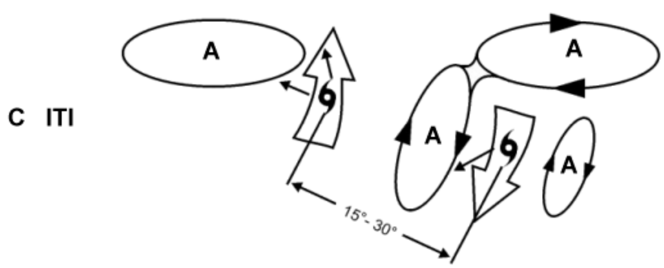


Figure 1-7c. Indirect TC Interaction (ITI).

- Monsoon Gyre Formation

- Monsoon Gyre Dissipation

Subtropical Ridge Modulation (by midlatitude troughs)

TC movement, intensification, and size evolution are closely linked, therefore, an "ideal TC forecast approach" may be defined as a fully integrated solution for the time evolution of the 3-dimensional three partial representations of the total TC circulation. TC track, intensity and size forecasts are then to be considered three partial representations of the total forecast solution.

1.6.2 BASIC APPROACH TO FORECASTING

1.6.2.1 Initial Positioning

The warning position is the best estimate of the center of the surface circulation at synoptic time. It is estimated from an analysis of all fix information received around that synoptic time. The analysis is aided by a computer-generated objective best-track scheme that weights fix information based on its statistical accuracy. The TDO includes synoptic observations and other information to adjust the position, testing consistency with the past direction, speed of movement and the influence of the different scales of motions. If the fix data are not available due to reconnaissance-platform malfunction or communication problems, or are considered unrepresentative, synoptic data and/or extrapolation from previous fixes are used.

1.6.2.2 Track Forecasting

In preparing the JTWC official forecast, the TDO evaluates a wide variety of information and employs Systematic Approach methodology. JTWC uses a standardized, three-phase TC motion-forecasting process to improve forecast accuracy and forecast-to-forecast consistency. Figure 1-1 depicts the three phases and inputs to the Systematic Approach outlined below.

1.6.2.2.1 Numerical Guidance Analysis Phase

NOGAPS analyses and prognoses at various levels are evaluated for position, development, and relevant synoptic features such as:

1) STR circulations;

2) midlatitude short/long-wave troughs and associated weaknesses in the STR;

3) monsoon surges;

4) cyclonic cells in the Tropical Upper-Tropospheric Trough (TUTT);

5) other TCs;

6) the distribution of sea-surface temperature.

The TDO determines into which pattern/region the TC falls, and what environmental influences and transitional mechanisms are indicated in the model fields. The process outlined above permits the TDO to develop an initial impression of the environmental steering influences to which the TC is, and will be, subjected to as depicted by NOGAPS. The NOGAPS analyses are then compared to the manually-plotted and analyzed charts prepared by JTWC and to the latest satellite imagery, in order to determine how well the NOGAPS-initialization process has conformed to the available synoptic data, and how well the resultant analysis fields agree with the synoptic situation inferred from the imagery. Finally, the TDO compares both the computer and manually-analyzed charts to monthly climatology in order to make a preliminary determination of to what degree the TC is, and will continue to be, subject to a climatological or non-climatological synoptic environment. Noting latitudinal and longitudinal displacements of STR and long-wave mid-latitude features is of particular importance, and will partially determine the relative weights given to climatologically or dynamically-based objective forecast guidance.

1.6.2.2.2 Objective Techniques Analysis Phase

By applying the systematic guidance with the NOGAPS model prognoses and real world conditions, performance characteristics for many of the objective techniques within the synoptic patterns/regions outlined in Section 1.6.1.3.1.1 have been determined. Estimating the likely biases of each of the objective-technique forecasts of TC track, intensity, and size given the current meteorological situation, the TDO eliminates those which are most likely inappropriate. The TDO also determines the degree to which the current situation is considered to be, and will continue to be, climatological by comparing the forecasts of the climatology-based objective techniques, dynamically-based techniques, and past motion of the present storm. Additionally, the spread of the set of objective forecasts, when plotted, is used to provide a measure of the predictability of subsequent motion, and the advisability of including a moderate-probability alternate forecast scenario in the prognostic reasoning message or warning (outside the western North Pacific). The directional spread of the plotted objective techniques is typically small well-before or well-after recurvature (providing high forecast confidence), and is typically large near the decision point of recurvature or non-recurvature, or during a quasi-stationary or erratic-movement phase. A large spread increases the likelihood of alternate forecast scenarios.

1.6.2.2.3 Forecast Development Phase

The TDO then constructs the JTWC official forecast giving due consideration to:

1) Interpretation of the TC-environment scenario depicted by numerical model guidance;

2) known properties of individual objective techniques given the present synoptic situation or geographic location;

3) the extent to which the synoptic situation is, and is expected to remain, climatological; and,

4) past statistical performance of the various objective techniques on the current storm.

The following guidance for weighting the objective techniques is applied:

1) Weight persistence strongly in the first 12 to 24 hours of the forecast period;

2) use conceptual models of recurring, dynamically-related meteorological patterns with the traits of the numerical and objective-aid guidance associated with the specific synoptic situation; and

3) give significant weight to the last JTWC forecast at all forecast times, unless there is significant evidence to warrant departure (also consider the latest forecasts from regional warning centers, as applicable).

1.6.3 INTENSITY FORECASTING

The empirically derived Dvorak (1984) technique is used as a first estimate for the intensity forecast. The TDO then adjusts the forecast after evaluating climatology and the synoptic situation. An interactive conditional-climatology scheme allows the TDO to define a situation similar to the system being forecast in terms of location, time of year, current intensity, and intensity trend. Synoptic influences such as the location of major troughs and ridges, and the position and intensity of the TUTT all play a large part in intensifying or weakening a TC. JTWC incorporates a checklist into the intensity-forecast procedure. Such criteria as upper-level outflow patterns, neutral points, sea-surface temperatures, enhanced monsoonal or cross-equatorial flow, and vertical wind shear are evaluated for their tendency to enhance or inhibit normal development, and are incorporated into the intensity-forecast process. In addition to climatology and synoptic influences, the first estimate is modified for interactions with land, with other tropical cyclones, and with extratropical features. Climatological and statistical methods are also used to assess the potential for rapid intensification.

1.6.4 WIND-RADII FORECASTING

The determination of wind-radii forecasts is a three-step process:

1) Low-level satellite drift winds, scatterometer and microwave imager 35-kt (18 m/s) wind speed analysis (see Chapter 2), and synoptic data are used to derive the current wind distribution.

2) The first estimate of the radii is then determined from statistically-derived empirical wind-radii models. The JTWC currently uses three models: the Tsui model, the Huntley model, and the Martin-Holland model. The latter model uses satellite-derived parameters to determine the size and shape of the wind profile associated with a particular tropical cyclone. The Martin-Holland model also incorporates latitude and speed of motion to produce an asymmetrical wind distribution. These models provide wind-distribution analyses and forecasts that are primarily influenced by the intensity forecasts. The analyses are then adjusted based on the actual analysis from step 1, and the forecasts are adjusted appropriately.

3) Synoptic considerations, such as the interaction of the cyclone with mid-latitude high pressure cells, are used to fine-tune the forecast wind radii.

1.6.5 EXTRATROPICAL TRANSITION

When a tropical cyclone moves into the mid-latitudes, it often enters an environment that is detrimental to the maintenance of the tropical cyclone's structure and energy-producing mechanisms. The effects of cooler sea-surface temperatures, cooler and dryer environmental air, and strong vertical wind shear all act to convert the tropical cyclone into an extratropical cyclone. JTWC indicates this conversion process is occurring by stating the tropical cyclone is "becoming extratropical." JTWC will indicate the conversion is expected to be complete by stating the system has "become extratropical." When a tropical cyclone is forecast to become extratropical, JTWC coordinates the transfer of warning responsibility to the appropriate agency.

1.6.6 TRANSFER OF WARNING RESPONSIBILITY

JTWC coordinates the transfer of the Department of Defense (DOD) warning responsibility for tropical cyclones entering or exiting its AOR. For tropical cyclones crossing 180E longitude in the North and South

Pacific Oceans, JTWC coordinates with NAVPACMETOCCEN, Pearl Harbor, Hawaii.

1.6.7 ALTERNATE JOINT TYPHOON WARNING CENTER (AJTWC)

In the event that JTWC should become incapacitated, the Alternate Joint Typhoon Warning Center assumes JTWC's functions. AJTWC is located at Yokosuka, Japan. Assistance in determining satellite reconnaissance requirements, and in obtaining the resultant data, is provided by the Air Force Weather Agency (AFWA).

Chapter 2
Reconnaissance And Fixes

2.1 GENERAL

JTWC utilizes numerous reconnaissance platforms and observational data sets to locate and analyze tropical cyclones. Satellite and radar have been the primary platforms for ”fixing” (location and intensity) tropical cyclones. Conventional land and ship weather observations complement the primary data set and, although sparse in areal coverage, remain the ”ground truth” for remotely- sensed data.

2.2 RECONNAISSANCE AVAILABILITY

2.2.1 SATELLITE

Near real-time analysis of visible, infrared and microwave satellite imagery by Air Force and Navy units provides JTWC with tropical cyclone positions and intensity estimates.

2.2.2 RADAR

This data provides location and speed of movement data for tropical cyclones in the proximity (usually within 175 nm (325 km) of radar sites located in Kwajalein, Guam, Japan, South Korea, China, Taiwan, Philippines, Hong Kong, Thailand and Australia. Doppler radars also provide data on cyclone intensity and structure through radial wind measurements in the vertical and horizontal planes.

2.2.3 SYNOPTIC

Analysis of conventional surface and gradient-level synoptic data provides JTWC with additional information on tropical cyclone position and intensity. This data is an important supplement to remotely-sensed platform fixes and are critical to the forecast process in situations where satellite, and radar fixes are not available or are considered unrepresentative.

2.3 SATELLITE RECONNAISSANCE SUMMARY

Per USCINCPACINST 3140.1W, the Commander, Pacific Air Forces (PACAF) is responsible for providing U.S. Pacific Command (USPACOM) tropical cyclone reconnaissance support. Through PACAFINST 15-102, Detachment 1, PACAF Air Operations Squadron (Det 1, PACAF AOS) acts as the Pacific Tropical Cyclone

Satellite Reconnaissance Network controller, tasking and monitoring all satellite reconnaissance efforts. Det 1, PACAF AOS Satellite Operations (SATOPS) is collocated with JTWC at Pearl Harbor, Hawaii. The network sites are listed in Table 2-1.

TABLE 2-1 USPACOM SATELLITE RECONNAISSANCE NETWORK SITES		
UNIT		ICAO
15 OSS/OSW	Hickam AFB, Hawaii	PHIK
18 OSS/OSW	Kadena AB, Japan	RODN
36 OSS/OSW	Andersen AFB, Guam	PGUA
Detachment 1, PACAF AOS	Pearl Harbor, HI	PGTW
607WS	Yongsan AIN, Republic of Korea	RKSZ
AFWA/XOGM	Offutt AFB, NE	KGWC
NAVCENTMETOCDET	Diego Garcia	FJDG

Direct readout network sites provide coverage of the North West Pacific, South China Sea, and south central Indian Ocean using DMSP and NOAA TIROS polar orbiting satellites. PACAFINST 15-102 requires each direct readout site to perform a minimum of two fixes per tropical cyclone per day if a tropical cyclone is within a site's coverage. Network direct readout site coverage is augmented by other sources of satellite-based reconnaissance. AFWA provides AOR-wide coverage to JTWC using recorded Real-time Data Smooth (RDS) DMSP and Global Area Coverage (GAC) NOAA AVHRR imagery. This imagery is recorded and stored on the satellites for later relay to a command readout site, which in turn passes the data to AFWA. Civilian contract weather support for the Army at Kwajalein Atoll provides additional satellite-based tropical cyclone reconnaissance in the Marshall Islands and east of the International Dateline as the opportunity arises. The NOAA/NESDIS Satellite Applications Branch at Camp Springs, Maryland (ICAO identifier KWBC) also provides six-hourly tropical cyclone position and intensity estimates in the JTWC AOR using METEOSAT and GMS geostationary platforms.

Network direct readout sites provide tropical cyclone positions and intensity estimates once JTWC issues either a TCFA or a warning. An example of the Dvorak code is shown in Figure 2-1. Each satellite-derived tropical cyclone position is assigned a Position Code Number (PCN) (Arnold and Olsen, 1974), which is a statistical estimate of fix position accuracy. The PCN is determined by: 1) the availability of visible landmarks in the image that can be used as references for precise gridding, and 2) the degree of organization of the tropical cyclone's cloud system (Table 2-2).

Once a tropical cyclone reaches an intensity of 55 kt, AFWA and Det 1, PACAF AOS SATOPS analyze the 35-kt wind distribution surrounding the tropical cyclone based on microwave satellite imagery. SATOPS provides three-hourly positions and six-hourly intensity estimates for all tropical cyclones in TCFA or warning status. Current intensity estimates are made using the Dvorak technique for both visible and enhanced infrared imagery. The standard relationship between tropical cyclone "T-number", maximum sustained surface wind speed, and minimum sea-level pressure (Atkinson and Holliday, 1977) for the Pacific is shown in Table 2-3. Subtropical cyclone intensity estimates are made using the Hebert and Poteat (1975) technique. Intensity estimates of tropical cyclones undergoing extratropical transition are made using the Miller and Lander (1997) technique.

Det 1, PACAF AOS SATOPS at Pearl Harbor uses hourly full-disk GMS imagery to observe 70% of JTWC's AOR from 80E to 180W (Figure 2-2). Animated geostationary imagery is a valuable tool for determining the location, intensity and motion of tropical cyclones. Additionally, animated water vapor channel imagery is useful for observing synoptic features that affect tropical cyclone development and movement.

The primary satellite reconnaissance system used during the 1998 tropical cyclone season was the Air

TABLE 2-2 POSITION CODE NUMBER (PCN)	
PCN	CENTER DETERMINATION/GRIDDING METHOD
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

TABLE 2-3 ESTIMATED MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

T-NUMBER	ESTIMATED WIND SPEED-KT(M/SEC)		MSLP(MB)(PACIFIC)
0.0	lt 25	lt (13)	—
0.5	25	(50)	—
1.0	25	(50)	—
1.5	25	(50)	—
2.0	30	(60)	1000
2.5	35	(70)	997
3.0	45	(90)	991
3.5	55	(110)	984
4.0	65	(130)	976
4.5	77	(154)	966
5.0	90	(180)	954
5.5	102	(204)	941
6.0	115	(230)	927
6.5	127	(254)	914
7.0	140	(280)	898

Force Mark IVB. SATOPS on an interim basis, also used the SMQ-11E, Navy Satellite Display System - Enhanced (NSDS-E) to access polar and geostationary data starting in December 1998.

The Air Force Mark IVB satellite system is undergoing a program-wide $6 million Pre-planned Product Improvement to increase its processing speed and networking capability. A client workstation is scheduled to be installed at JTWC in late 1999 and become the primary satellite reconnaissance display and analysis system. The Mark IVB will then display NOAA Advanced Very High Resolution Radiometer (AVHRR), DMSP Operational Linescan System (OLS), Special Sensor Microwave/Imager (SSM/I), Microwave/Sounder (SSM/T1 and SSM/T2), and also geostationary visible, infrared and water vapor channel imagery.

NOAA TIROS AVHRR imagery provides five channels of imagery: visible, near and middle IR, and two in the far IR channels. DMSP OLS provides imagery in two channels: visible/near IR (commonly referred as broadband visible), and far IR.

2.3.1 SATELLITE PLATFORM SUMMARY

Imagery was received from various sensors on three DMSP (F12, F13 and F14) and three NOAA (N12, N14 and N15) satellites during 1998.

2.3.2 STATISTICAL SUMMARY

As directed by Base Realignment and Closure (1995), the satellite operations section relocated from Guam to Hawaii with JTWC in October through December of 1998 and officially became operational on 1 Jan 1999. During 1998, the PACOM Tropical Cyclone Satellite Reconnaissance Network and other agencies provided JTWC with 6,032 fixes: 2,420 NWP, 511 North Indian Ocean, and 3,101 Southern Hemisphere. SATOPS provided 3,221, accounting for nearly 53% of all fixes.

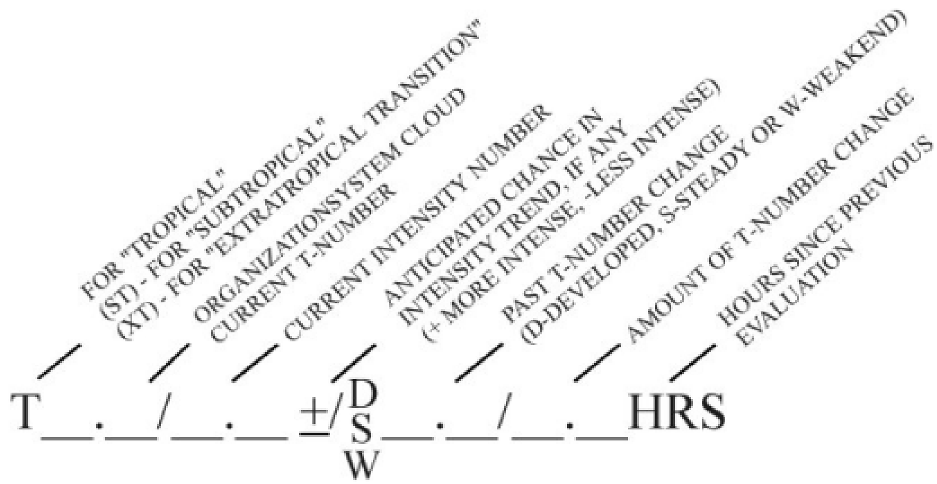


Figure 2-1. Dvorak code for estimating current and forecast intensity from satellite data. In the example, the current T-number is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the evaluation conducted 24 hours earlier.

2.3.3 APPLICATIONS OF NEW TECHNIQUES AND TECHNOLOGY

SATOPS began use of microwave imagery from the Tropical Rainfall Measurement Mission research (TRMM) satellite. This low-earth orbit satellite has a nine-channel passive microwave radiometer similar to the DMSP SSM/I but at half the altitude. While its usable swath width is roughly half as wide as DMSP SSM/I, TRMM's resolution is much better. Additionally, its equatorial orbit (35 degree inclination angle) provides better coverage of JTWC's tropical area of responsibility. The acquisition of DMSP F14 data in the early summer helped increase the area covered by microwave imagery. Additionally, to give the TDO a better statistical value for each satellite derived fix, SATOPS continued to use animated geostationary imagery and multispectral display capability to apply Position Code Numbers (PCN) (Table 2-4) and fix codes to a particular tropical cyclone pattern based on sensor type. The XT technique (Miller and Lander, 1997) continued to be used operationally to better estimate tropical cyclones undergoing extratropical transition.

Table 2-4 POSITION CODE NUMBER (PCN) CRITERIA AND FIX CODES FOR TC LOW-LEVEL CCs FROM SATELLITE (Note 1)

PCN	PCN	Definitions	Sensor /technique type and fix code					
Grid by Geography (note 2)	Grid by Ephemeris (note 2)		IR	Vis	Both	SSM/I only (note 3)	Vis/IR &SSM/I (note 3)	Anmtn (note 4)
1	2	Eye						
(EYE)	(EYE)	CDO type eye, geometric center (regular, round, any diameter) (note 6)	1	2	3	4	S	A
(EYE)	(EYE)	Small eye (irregular/ragged, diameter 30 nm on long axis) (note 6)	5	6	7	8	S	A
3	4	Well defined CC						
(EYE)	(EYE)	Eye(ragged/irregular, diameter &30nm center &1/2 enclosed by wall cloud (note 6)	9	10	11	12	S	A
(EYE)	(EYE)	Tightly curved band/banding type eye (band curves at least 1/2 distance around center, diameter 90 nm)	13	14	15	16	S	A
(LLCC)	(LLCC)	Exposed low-level CC	17	18	19	20	S	A
(CDO)	(CDO)	Small CDO (round with well defined edges, positioned near geometric center, diameter 80 nm)		21	22	23	S	A
(EMB)	(EMB)	Small embedded center (diameter 80 nm)	24		25	26	S	A
(CDO)	(CDO)	Large CDO (with clear indications of shearing, low-level cloud lines, or overshooting tops that bias low-level center position away from the geometric center, diameter 80 nm)		27	28	29	S	A
(CDO)	(CDO)	Any CDO or Embedded Center with low-level CC clearly visible on co-registered SSM/I (note 7)	30	31	32	33	S	

Table 2-4 POSITION CODE NUMBER (PCN) CRITERIA AND FIX CODES FOR TC LOW-LEVEL CCs FROM SATELLITE (Note 1)

5	6	Poorly Defined						
		Large eye (ragged/irregular, 30 nm diameter on long axis, 1/2 enclosed by wall cloud)	34	35	36	37	S	A
		Spiral banding systems (convective curvature) not classifiable as banding eye or tightly curved band	38	39	40	41	S	A
		Large CDO		43	44	45	S	A
		Embedded center positioned with IR	46					A
		Partially exposed low-level centers with the CC less than half exposed	47	48	49	50	S	A
		Cloud minimum wedge/cold comma	51	52	53	54	S	A
		Central cold cover	55	56	57	58	S	A
		Cirrus outflow - upper level outflow provides the only circulation parameters	59	60	61	62	S	A
		Poorly organized low-level center evident only in high resolution animation (Vis/IR or both)						
		All others						
		Monsoon depressions or multiple cloud clusters, positioned using any of the following methods:	Any combination of Vis , IR/EIR					
		Cirle method	68					
		Conservative feature	69					A
		Animation	70					
		Extrapolation	71					

Note 1: Use the following steps to determine the PCN and Fix Code: a. Based on the analysis of the circulation parameters, determine a TC low-level CC position. b. Go to Table 2-2, then to the definitions column. Choose a PCN based on the cloud pattern, discrete measurements, as necessary, and/or technique used to determine the position. c. Move across to the Fix Code columns, and based on the sensor(s) used, select a fix code.

Note 2: Odd PCNs (1, 3, 5) are gridded with geography, the low-level CC being within 10 degrees (600 nm) of the geographic feature used for gridding. Even PCNs (2, 4, 6) are gridded with ephemeris, or the low-level CC is not within 10 degrees (600 nm) of the geographic feature used for gridding.

Note 3: SSM/I only fixes - Use PCN of 5 or 6, and fix code based on Note 1, para a c.

Note 4: Append S to the numerical fix code entry to indicate Special Sensor Microwave Imager (SSM/I) and visible and/or infrared data was used in determining the low-level CC (i.e. 18S). Defense Meteorological Satellite Program (DMSP) fixes only. For the purposes of this fix code, SSM/I (S) and Animation (A) are mutually exclusive.

Note 5: Append A to the numerical fix code entry to indicate animation was used in determining the low-level CC (i.e. 11A). Geostationary fixes only. For the purposes of this fix code, SSM/I (S) and Animation (A) are mutually exclusive.

Note 6: For fix code entries 1-9, encode 01-09.

Note 7: In order to use SSM/I data to position low-level CCs, you must be able to correct the navigation/gridding and interrogate the SSM/I imagery directly for latitude/longitude (DMSP fixes only).

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE

Research is being conducted to develop a method of integrating passive microwave radiometer imagery into the Dvorak position and intensity estimate technique. This technique currently relies exclusively on visible and enhanced infrared. Using microwave imagery – which can see through obscuring layers of cirrostratus cloud decks – will provide early warning of significant changes in tropical cyclone convective structure. Additionally, SATOPS anticipates far more frequent and usable scatterometer data from the NASA QuikSCAT satellite, which is scheduled for launch in mid-1999. This satellite, whose active microwave sensor measures backscatter from the ocean surface to determine both the direction and speed of surface winds, will have a swath width of approximately 1,800 kilometers, over twice that of the European ERS-2 scatterometer. Increased swath width will result in more frequent useable passes as well as the capability to routinely determine 35-knot wind distribution around strong tropical cyclones.

2.4 RADAR RECONNAISSANCE SUMMARY

Of the 27 NWP significant tropical cyclones, 6 passed within range of land-based radar with sufficient precipitation and organization to be fixed. A total of 88 land-based radar fixes were logged at JTWC. As defined by the World Meteorological Organization (WMO), the accuracy of these fixes falls within three categories: good [within 10 km (5 nm)], fair [within 10 - 30 km (5 - 16 nm)], and poor [within 30 - 50 km (16 - 27 nm)]. Of the 88 radar fixes encoded in this manner, 15 were good, 45 were fair, and 28 were poor. The radar network provided timely and accurate fixes which allowed JTWC to better track and forecast tropical cyclone movement. In the Southern Hemisphere, 20 radar reports were logged for tropical cyclones. No radar fixes were received for the North Indian Ocean.

2.5 TROPICAL CYCLONE FIX DATA

Table 2-5a shows the number of fixes per platform for each individual tropical cyclone for the NWP. Totals and percentages are also shown. Similar information is provided for the North Indian Ocean in Table 2-5b, and for the South Pacific and South Indian Ocean in Table 2-5c.

TABLE 2-5a WESTERN NORTH PACIFIC OCEAN FIX SUMMARY FOR 1998

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR(P/F/G)	SYNOPTIC	TOTAL
01W	72	1	0	0	73
02W NICHOLE	93	1	15/0/0	0	109
03W	31	0	0	0	31
04W OTTO	85	1	0	2	88
05W PENNY	122	1	0	2	125
06W REX	359	3	0	0	362
07W	35	0	0	0	35
08W STELLA	94	2	0	8	104
09W	19	0	0	0	19
10W TODD	102	1	0	4	107
11W VICKI	143	1	3/6/1	13	167
12W	27	0	0	0	27
13W WALDO	38	0	0	7	45
14W YANNI	98	2	5/4/5	11	125
15W	51	1	0	3	55
16W	51	0	0	3	54
17W	15	0	0	2	17
18W ZEB	205	2	4/2/4	33	248
19W ALEX	27	0	1/6/5	1	39
20W BABS	334	4	0/27/0	14	379
21W CHIP	61	0	0	1	62
22W DAWN	53	0	0	0	53
23W ELVIS	43	1	0	1	45
24W FAITH	134	1	0	1	136
25W GIL	68	1	0	2	71
26W	32	0	0	1	33
27W	43	0	0	0	43
TOTALS	2435	23	88	99	2652
PERCENTAGE OF TOTAL	92	1	3	4	100

TABLE 2-5b NORTH INDIAN OCEAN FIX SUMMARY FOR 1998

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR	SYNOPTIC	TOTAL
01B	110	1	0	0	111
02A	9	2	0	0	11
03A	109	3	0	1	113
04A	10	0	0	0	10
05A	24	0	0	1	25
06B	49	0	0	0	49
07B	119	0	0	1	120
08A	84	1	0	0	85
TOTALS	514	7	0	3	524
PERCENTAGE OF TOTAL	98	1	0	1	100

TABLE 2-5c SOUTH PACIFIC AND SOUTH INDIAN OCEAN FIX SUMMARY FOR 1998

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR(P/F/G)	SYNOPTIC	TOTAL
01S	79	2	0	0	81
02P LUSI	96	4	0	1	101
03P	38	2	0	2	42
04P MARTIN	42	0	0	0	42
05P	76	3	0	4	83
06P OSEA	56	0	0	0	56
07P PAM	73	0	0	0	73
08S	54	0	1/2/0	2	59
09S SELWYN	125	3	0	0	128
10P RON	120	0	0	0	120
11P SUSAN	121	3	0	0	124
12P KATRINA	492	5	0/0/5	18	520
13P	50	2	0	0	52
14P LES	152	1	1/0/0	1	155
15S TIFFANY	151	1	0/7/4	0	163
16P TUI	21	0	0	0	21
17P URSULA	13	0	0	0	13
18P VELI	31	0	0	0	31
19P WES	49	0	0	1	50
20S ANACELLE	114	2	0	0	116
21S	43	1	0	0	44
22P VICTOR	187	2	0	2	191
23P	58	1	0	1	60
24S	32	1	0	0	33
25P MAY	48	0	0	0	48
26S DONALINE	57	1	0	0	58
27S ELSIE	227	2	0	0	229
28S FIONA	76	2	0	0	78
29P YALI	176	3	0	0	179
30P NATHAN	180	2	0	2	184
31P ZUMAN	180	3	0	0	183
32S	167	2	0	1	170
33S	13	0	0	0	13
34S	79	0	0	0	79
35S	46	2	0	0	48
36P ALAN	46	0	0	0	46
37P BART	20	0	0	0	20
TOTALS	3588	51	20	34	3693
PERCENTAGE OF TOTAL	97	1	1	1	100

Chapter 3

Summary Of North West Pacific And Northern Indian Ocean Tropical Cyclones

3.1 NORTH WEST PACIFIC OCEAN TROPICAL CYCLONES

The 1998 tropical cyclone season was notable for the shift of the cyclone genesis region west, the lack of tropical cyclone activity and the late tropical cyclone season start[1]. These events as compared to the 1997 tropical cyclone season represented a pendulum swing to the opposite. The 1997 season was noted for tropical cyclone genesis near or east of the dateline, a slight increase in the number of tropical cyclones and an early start of tropical cyclone activity.

1998 tropical cyclone genesis occurred mainly in the Philippine and South China Seas (Figure 3-1). As compared to the 15-year average, tropical cyclone formation east of the Mariana Islands was 70% less while the Philippine Sea region experienced nearly average formation. Of special note was the South China Sea, where a comparison of the 1998 formation numbers to the 15-year average indicates that double the amount of tropical cyclones formed in that region during 1998.

The 1998 calendar year total of 27 tropical cyclones (Table 3-1), which included 9 Tropical Depressions, 9 Tropical Storms and 9 Typhoons, was 4 below the long-term annual average. The 1998 tropical cyclone activity also represented the lowest annual number of tropical cyclones to occur in 10 years.

The "start" of the 1998 tropical cyclone season, as signaled by the first JTWC warning issued, commenced on 7 July 1998. This was the latest "start" of the North West Pacific Ocean tropical cyclone season ever recorded by the JTWC. Although the 1998 tropical cyclone number was relatively low, the forecast challenge presented by these cyclones was high. Of note was the forecast challenge of TY Rex (06W), whose movement and intensity were affected by a Mid-tropospheric Subtropical Ridge and a Tropical Upper Tropospheric Trough (TUTT).

3.2 NORTH INDIAN OCEAN TROPICAL CYCLONES

In 1998 eight significant tropical cyclones (Table 3-5 and Figure 3-5a and 3-5b) occurred in this region causing widespread flooding and numerous fatalities especially in Bangladesh and the Gujarat, Kutch and Saurashtra regions of India.

There was an even split between the Bay of Bengal and Arabian Sea for tropical cyclone development with the most intense tropical cyclone (TC 03A with maximum winds of 105 kt) occurring in the Arabian Sea.

TC 03A was unusual because of its record maximum and its June occurance. This cyclone developed outside the climatologically favored Spring and Fall tropical cyclone formation period expected for North Indian Ocean (Table 3-6).

[1]Unless otherwise stated, the data set used for comparison is JTWC tropical cyclone data for the period from 1959 to 1998.

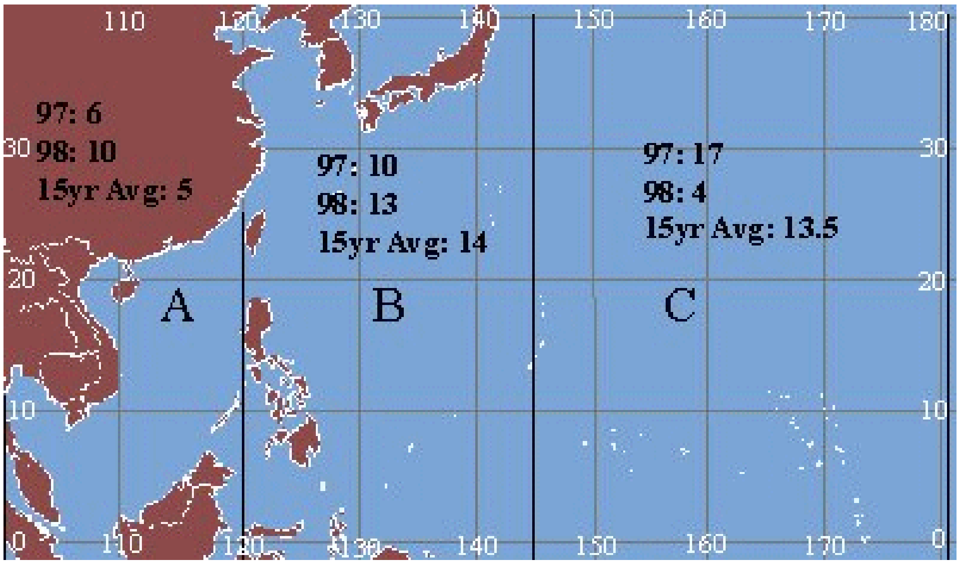


Figure 3-1. Comparison of the number of tropical cyclones that developed within 3 designated areas for 1997, 1998 and the 15-year average.

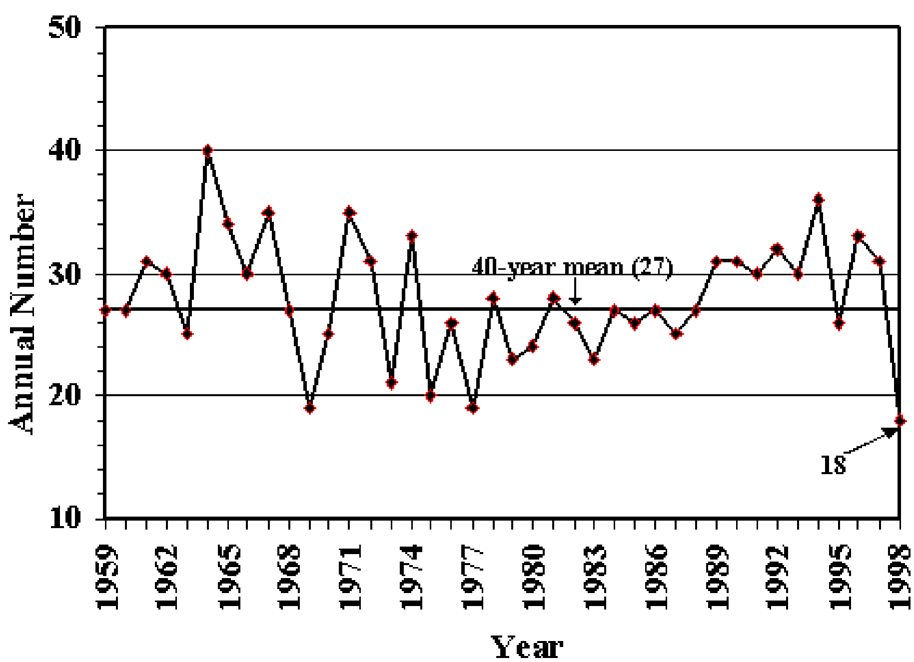


Figure 3-2. Tropical Cyclones of Tropical Storm or greater intensity in the Western North Pacific (1960-1998)

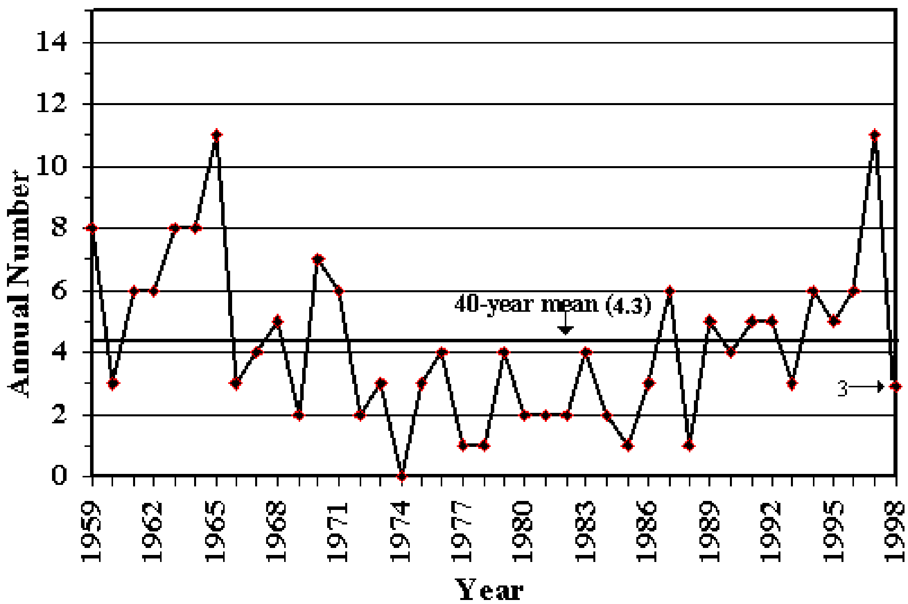


Figure 3-3. Number of Western North Pacific Super Typhoons (1960-1998)

TABLE 3-1 WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 1998

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	ESTIMATED MAXIMUM INTENSITY KT (M/SEC)	ESTIMATED MSLP (MB)
01W TD	07 JUL-11 JUL	15	30 (15)	1000
02W TS NICHOLE	08 JUL- 12 JUL	16	50 (26)	987
03W TS NO NAME*	25 JUL- 26 JUL	6	45 (23)	991
04W TY OTTO**	02 AUG - 05 AUG	13	100 (52)	944
05W TS PENNY	06 AUG - 11 AUG	18	60 (30)	980
06W TY REX	24 AUG - 07 SEP	57	115 (58)	927
07W TD	02 SEP - 04 SEP	9	30 (15)	1000
08W TY STELLA	12 SEP - 16 SEP	18	65 (33)	976
09W TD	13 SEP	3	25 (12)	1002
10W STY TODD***	16 SEP - 20 SEP	17	130 (67)	910
11W TY VICKI	17 SEP - 23 SEP	25	90 (46)	954
12W TD	18 SEP - 19 SEP	7	30 (15)	1000
13W TS WALDO	20 SEP - 21 SEP	9	45 (23)	991
14W TY YANNI	25 SEP - 01 OCT	26	80 (41)	963
15W TD	03 OCT - 05 OCT	11	30 (15)	1000
16W TD	05 OCT - 07 OCT	11	30 (15)	1000
17W TD	06 OCT - 07 OCT	5	30 (15)	1000

TABLE 3-1 WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 1998				
18W STY ZEB	09 OCT - 18 OCT	34	155 (80)	878
19W TS ALEX	11 OCT - 13 OCT	8	45 (23)	991
20W STY BABS	14 OCT - 27 OCT	55	135 (69)	904
21W TS CHIP	12 NOV - 15 NOV	13	50 (26)	987
22W TS DAWN	18 NOV - 20 NOV	8	45 (23)	991
23W TS ELVIS	24 NOV - 26 NOV	10	45 (23)	991
24W TY FAITH	08 DEC - 14 DEC	26	90 (46)	954
25W TS GIL	09 DEC - 13 DEC	15	35 (18)	997
26W TD	17 DEC - 19 DEC	7	25 (12)	1002
27W TD	19 DEC - 22 DEC	12	30 (15)	1000
Total Warnings Issued: 454				
*TS 03W was designated a tropical storm during post analysis. Hence, no name was assigned during the lifecycle of the system.				
**TY Otto was upgraded to typhoon intensity during post analysis.				
***STY Otto was upgraded to super typhoon intensity during post analysis.				

TABLE 3-2 DISTRIBUTION OF WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959 - 1998

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	000	010	010	100	000	001	111	512	423	210	200	200	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	001	000	001	100	010	210	210	810	41	400	100	100	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	010	010	100	010	211	114	320	313	510	322	101	100	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	000	010	000	100	201	000	512	701	313	311	301	020	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	000	000	001	100	000	310	311	301	220	510	000	210	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	000	000	000	000	201	200	611	350	521	331	420	101	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	110	020	010	100	101	310	411	322	531	201	110	010	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	000	000	000	100	200	100	310	531	532	112	122	101	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	010	000	110	100	010	100	332	343	530	211	400	010	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	000	001	000	100	000	202	120	341	400	510	400	000	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	100	000	010	100	000	000	210	210	204	410	110	010	13 6 4
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	000	100	000	000	000	110	021	421	220	321	130	000	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	010	000	010	200	230	200	620	311	511	310	110	000	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	100	000	001	000	000	220	410	320	411	410	200	210	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23

TABLE 3-2 DISTRIBUTION OF WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959 - 1998

	000	000	000	000	000	000	430	231	201	400	030	000	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	010	000	010	010	100	121	230	232	320	400	220	020	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	100	000	000	001	000	000	010	411	410	321	210	002	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	100	010	000	110	200	200	220	130	410	000	110	020	14 11 0
1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	521	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
1987	1	0	0	1	0	2	4	4	7	2	3	1	25
	100	000	000	010	000	110	400	310	511	200	120	100	18 6 1
1988	1	0	0	0	1	3	2	5	8	4	2	1	27
	100	000	000	000	100	111	110	230	260	400	200	010	14 12 1
1989	1	0	0	1	2	2	6	8	4	6	3	2	35
	010	000	000	100	200	110	231	332	220	600	300	101	21 10 4
1990	1	0	0	1	2	4	4	5	5	5	4	1	31
	100	000	000	010	110	211	220	500	410	230	310	100	21 9 1
1991	0	0	2	1	1	1	4	8	6	3	6	0	32
	000	000	110	010	100	100	400	332	420	300	330	000	20 10 2
1992	1	1	0	0	0	3	4	8	5	6	5	0	33
	100	010	000	000	000	210	220	440	410	510	311	000	21 11 1
1993	0	0	2	2	1	2	5	8	5	6	4	3	38
	000	000	011	002	010	101	320	611	410	321	112	300	21 9 8
1994	1	0	1	0	2	2	9	9	8	7	0	2	41
	001	000	100	000	101	020	342	630	440	511	000	110	21 15 5
1995	1	0	0	0	1	2	3	7	7	8	2	3	34
	001	000	000	000	010	020	210	421	412	512	020	012	15 11 8
1996	0	1	0	2	2	0	7	10	7	5	6	3	43
	000	001	000	011	110	000	610	433	610	212	132	111	21 12 10

TABLE 3-2 DISTRIBUTION OF WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959 - 1998

1997	1	0	0	2	3	3	4	8	4	6	1	1	33
	010	000	000	110	120	300	310	611	310	411	100	100	23 8 2
1998	0	0	0	0	0	0	3	3	8	6	3	4	27
	000	000	000	000	000	000	012	210	413	213	030	112	9 9 9
(1959-1998)													
MEAN	0.6	0.3	0.6	0.7	1.2	2.0	4.5	6.3	5.7	4.7	2.9	1.5	30.8
CASES	22	11	23	29	48	79	178	251	227	188	116	60	1233

The criteria used in TABLE 3-2 are as follows:

1) If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.

2) If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 3-3 WESTERN NORTH PACIFIC TROPICAL CYCLONES

TYPHOONS (1945-1959)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.3	0.1	0.3	0.4	0.7	1	2.9	3.1	3.3	2.4	2	0.9	16.4
CASES	5	1	4	6	10	15	29	46	49	36	30	14	245

TYPHOONS (1960-1998)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.3	0.1	0.2	0.4	0.7	1.1	2.8	3.5	3.5	3.3	1.7	0.7	18.3
CASES	10	2	8	16	27	41	107	134	133	126	63	27	694

TROPICAL STORMS AND TYPHOONS (1945-1959)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.4	0.1	0.5	0.5	0.8	1.6	2.9	4	4.2	3.3	2.7	1.2	22.2
CASES	6	2	7	8	11	22	44	60	64	49	41	18	332

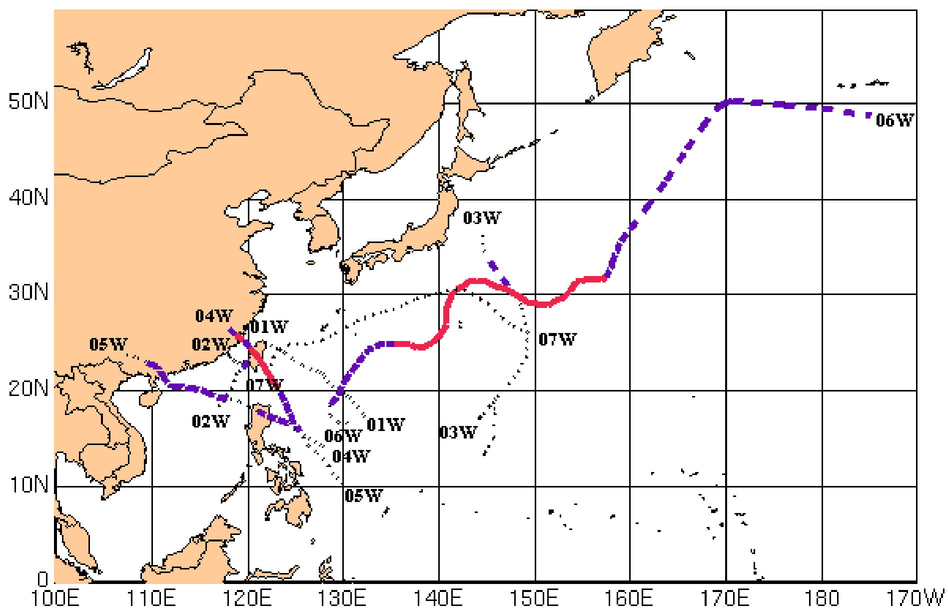
TROPICAL STORMS AND TYPHOONS (1960-1998)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.5	0.2	0.4	0.7	1.2	1.8	4.3	5.7	5.2	4.4	2.7	1.3	28.5
CASES	20	9	17	25	44	70	165	218	198	167	104	49	1085

TABLE 3-4 TROPICAL CYCLONE FORMATION ALERTS FOR THE WESTERN NORTH PACIFIC OCEAN FOR 1976-1998

YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	PROBABILITY OF TCFA WITHOUT WARNING*	PROBABILITY OF TCFA BEFORE WARNING
1976	34	25	25	26%	100%
1977	26	20	21	23%	95%
1978	32	27	32	16%	84%
1979	27	23	28	15%	82%
1980	37	28	28	24%	100%
1981	29	28	29	3%	96%
1982	36	26	28	28%	93%
1983	31	25	25	19%	100%
1984	37	30	30	19%	100%
1985	39	26	27	33%	96%
1986	38	27	27	29%	100%
1987	31	24	25	23%	96%
1988	33	26	27	21%	96%
1989	51	32	35	37%	91%
1990	33	30	31	9%	97%
1991	37	29	31	22%	94%
1992	36	32	32	20%	100%
1993	50	35	38	30%	92%
1994	50	40	40	20%	100%
1995	54	33	35	39%	94%
1996	41	39	43	,5%	91%
1997	36	30	33	17%	91%
1998	38	18	27	53%	67%
(1976-1998) MEAN:	37	26	30	30%	87%
TOTALS:	856	653	697	697	

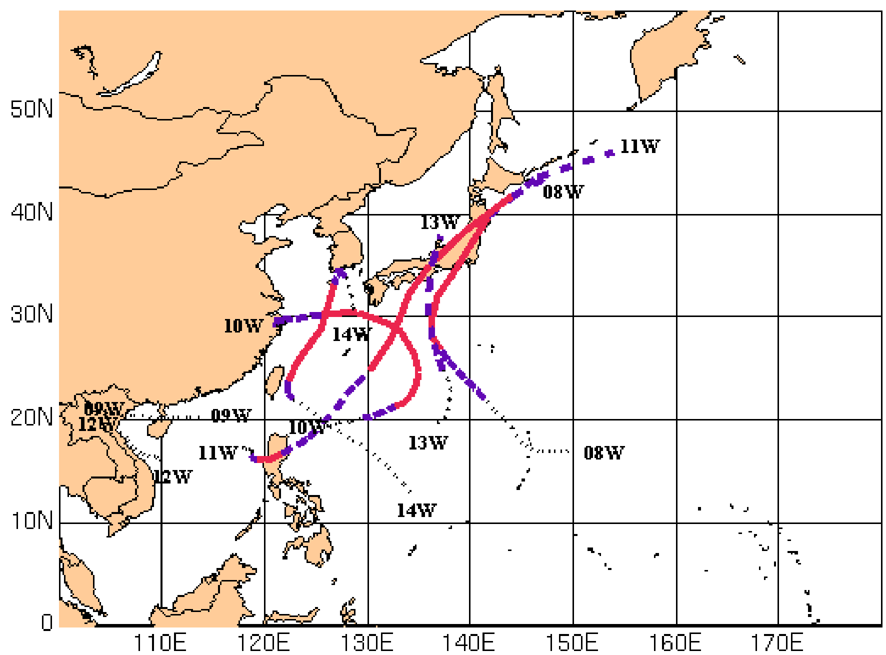
* Percentage of initial TCFA's not followed by warnings.



NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
07 JUL 98 - 02 SEPT 98

MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS

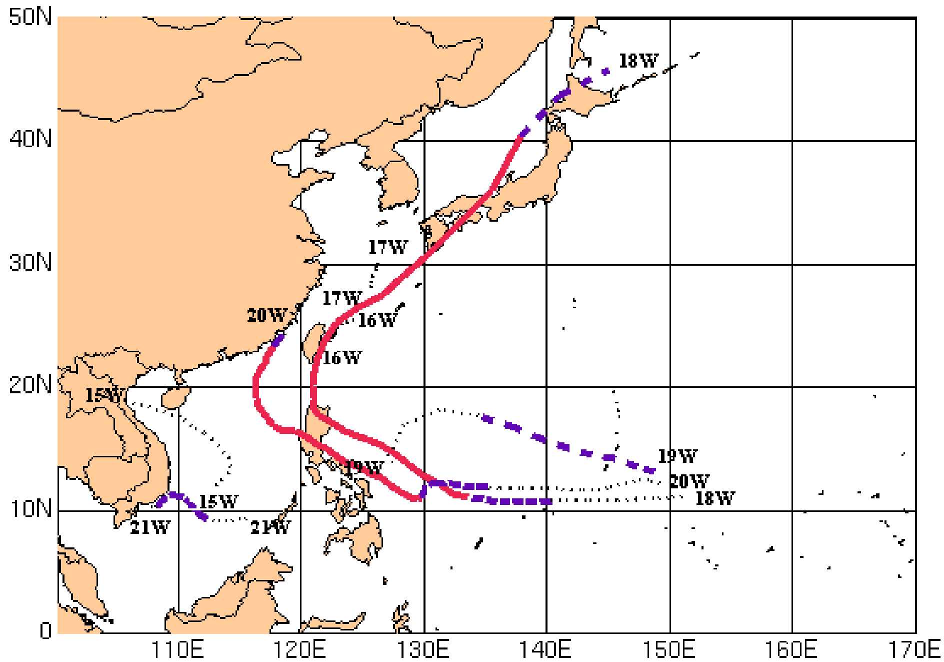
01W TD	07 JUL - 11 JUL
02W TS NICHOLE	08 JUL - 12 JUL
03W TS NO NAME	25 JUL - 26 JUL
04W TY OTTO	02 AUG - 05 AUG
05W TY PENNY	06 AUG - 11 AUG
06W TY REX	24 AUG - 07 SEPT
07W TD	02 SEPT - 04 SEPT



NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
12 SEPT - 25 SEPT

MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS

08W TY STELLA	12 SEPT - 16 SEPT
09W TD	13 SEPT - 13 SEPT
10W STY TODD	16 SEPT - 20 SEPT
11W TS VICKI	17 SEPT - 23 SEPT
12W TD	18 SEPT - 19 SEPT
13W TS WALDO	20 SEPT - 21 SEPT
14W TY YANNI	25 SEPT - 10 OCT



NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
03 OCT 98 - 12 NOV 98

MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS

15W TD	03 OCT - 05 OCT
16W TD	05 OCT - 07 OCT
17W TD	06 OCT - 07 OCT
18W STY ZEB	09 OCT - 18 OCT
19W TS ALEX	11 OCT - 12 OCT
20W STY BABS	14 OCT - 27 OCT
21W TS CHIP	12 NOV - 15 NOV

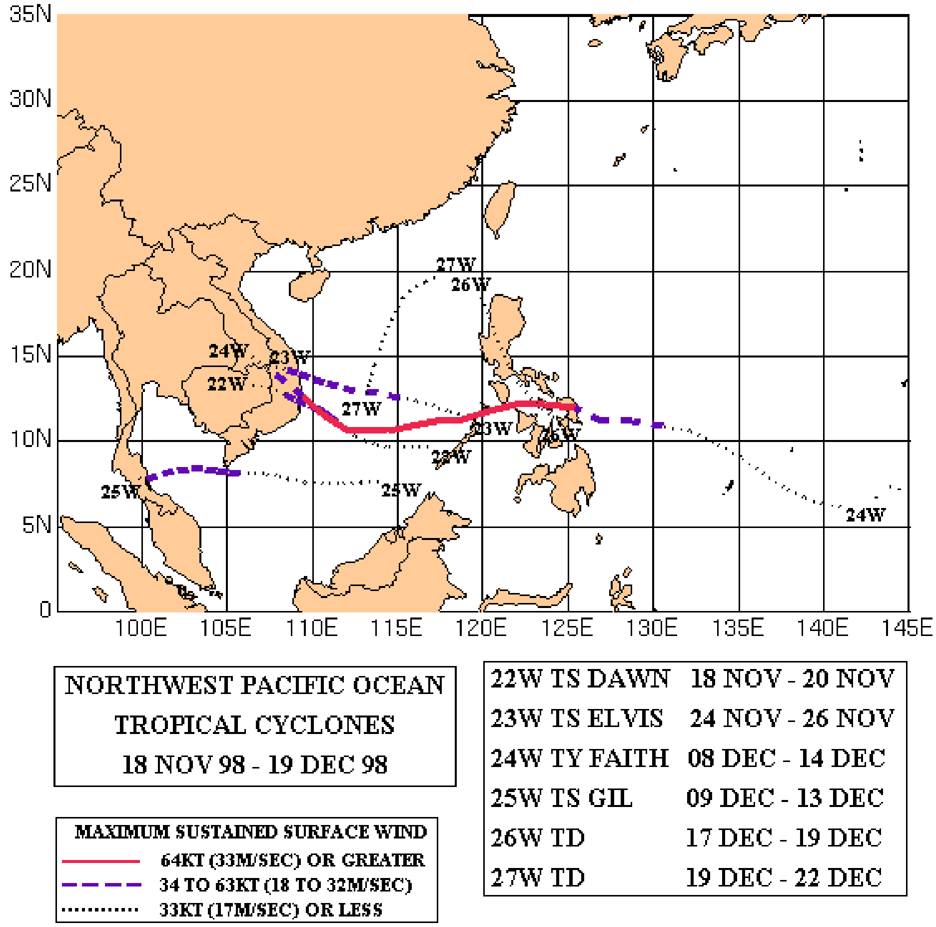

35N
30N
25N
20N
15N
10N
5N
0
100E
105E
110E
115E
120E
125E
130E
135E
140E
145E
27W
26W
24W
23W
22W
27W
23W
26W
22W
25W
25W
24W
NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
18 NOV 98 - 19 DEC 98
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS
22W TS DAWN 18 NOV - 20 NOV
23W TS ELVIS 24 NOV - 26 NOV
24W TY FAITH 08 DEC - 14 DEC
25W TS GIL 09 DEC - 13 DEC
26W TD 17 DEC - 19 DEC
27W TD 19 DEC - 22 DEC

TABLE 3-5 NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES FOR 1998					
TROPICAL CYCLONE	PERIOD OF WARNING	NUMBERS OF WARNINGS ISSUED	ESTIMATED MAX INTENSITY		EST MSLP
			KT (M/SEC)		(MB)
01B	18 MAY 20 MAY	11	70	(35)	972
02A	28 MAY 29 MAY	5	35	(18)	997
03A	04 JUN 09 JUN	22	105	(53)	938
04A	30 SEP 01 OCT	3	35	(18)	997
05A	16 OCT 18 OCT	5	35	(18)	997
06B	14 NOV 16 NOV	6	85	(43)	958
07B	12 NOV 23 NOV	9	75	(38)	968
08A	13 DEC 17 DEC	19	65	(33)	976
			AVG	AVG	AVG
TOTAL		80	63.13	(32)	975.38

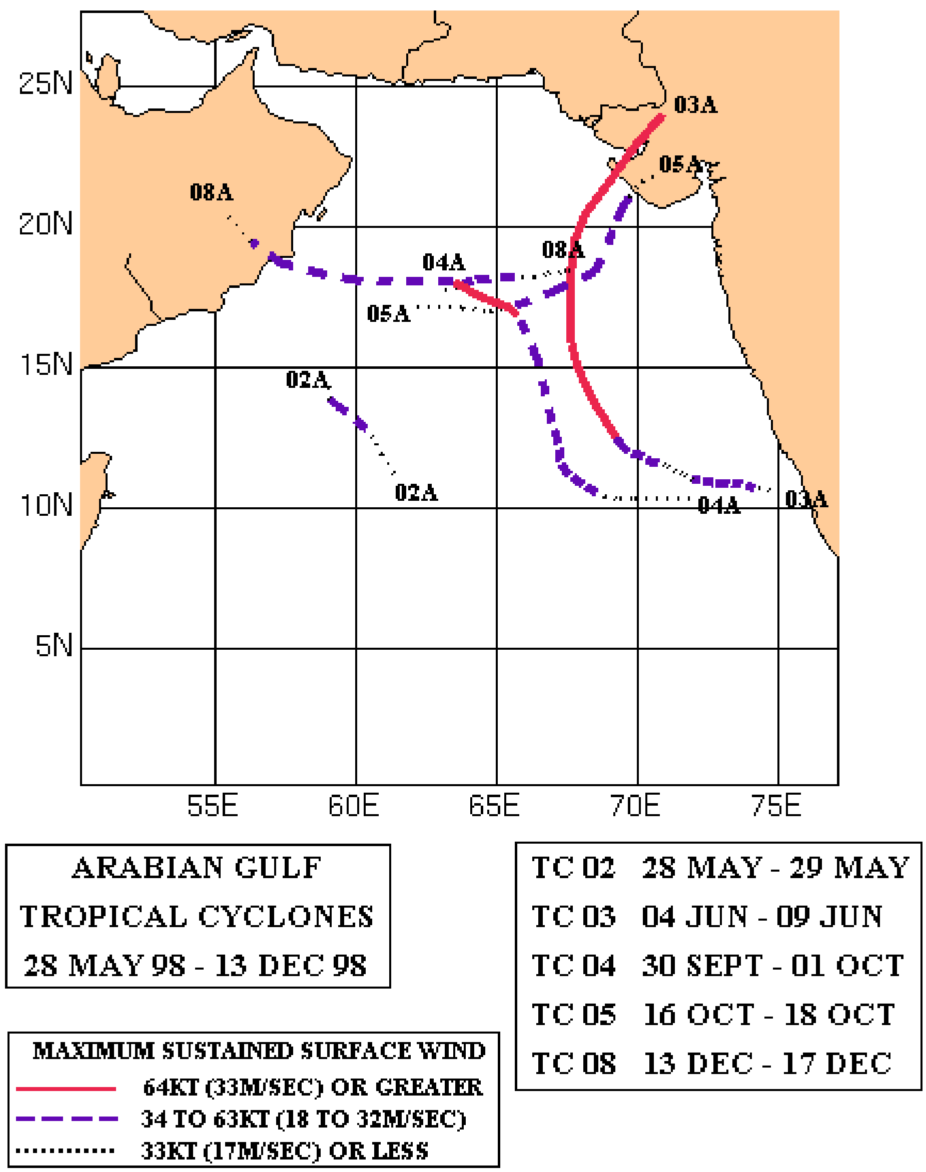
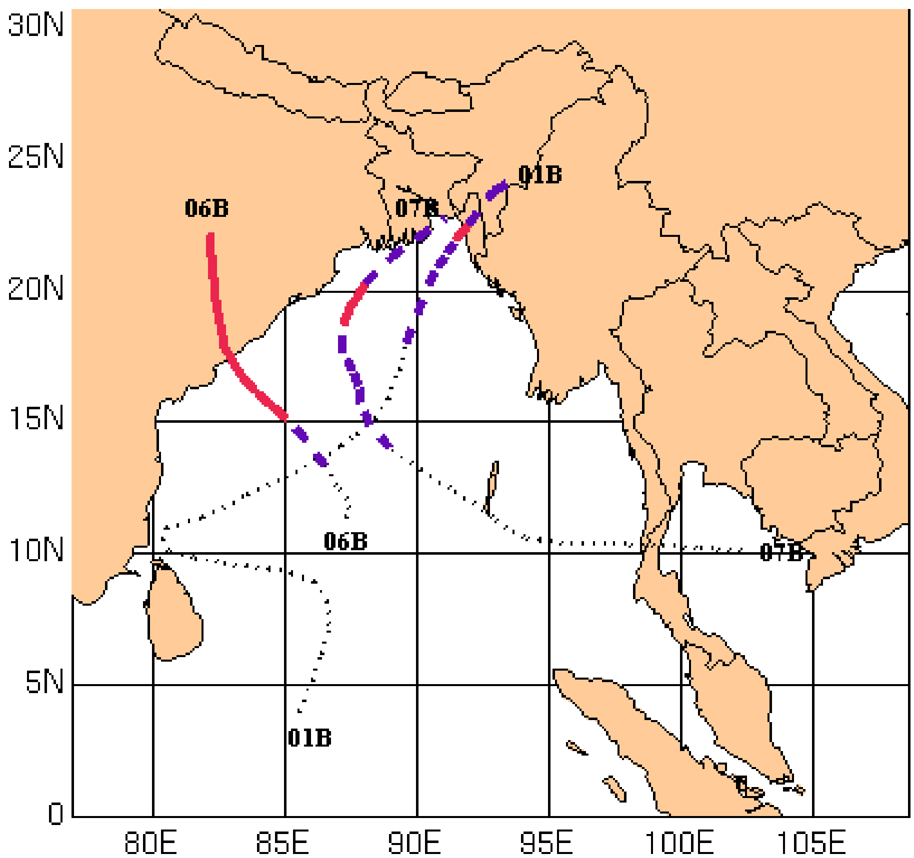


Figure 3-5a. Past data indicates annual mean genesis location of WNP tends to be east of normal during the La Nia or ENSO cold phase. Consistent with past observations for a La Nia episode, the annual mean genesis location for all TCs during 1998 was substantially north and west (Figure 3-5a) of the long term average TC genesis position. Further review of the 1998 genesis locations revealed 10 tropical cyclones developed in the South China Sea (100-120 degrees longitude), 10 in the Philippine Sea (120-145 degrees longitude), and only 4 east of Guam (145-180 degrees longitude).



BAY OF BENGAL
TROPICAL CYCLONES
18 MAY 98 - 20 NOV 98

TC 01	18 MAY - 20 MAY
TC 06	14 NOV - 16 NOV
TC 07	20 NOV - 23 NOV

MAXIMUM SUSTAINED SURFACE WIND

- 64KT (33M/SEC) OR GREATER
- 34 TO 63KT (18 TO 32M/SEC)
- 33KT (17M/SEC) OR LESS

TABLE 3-6 DISTRIBUTION OF NORTHERN INDIAN OCEAN TROPICAL CYCLONES FOR 1975 - 1998

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
	010	000	000	000	200	000	000	000	000	100	020	000	3 3 0
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
	000	000	000	010	000	010	000	000	010	010	000	010	0 5 0
1977	0	0	0	0	1	1	0	0	0	1	0	2	5
	000	000	000	000	010	010	000	000	000	010	000	110	1 4 0
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
	000	000	000	000	010	000	000	000	000	010	200	000	2 2 0
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
	000	000	000	000	100	010	000	000	011	010	011	000	1 4 2
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
	000	000	000	000	000	000	000	000	000	000	010	010	0 2 0
1981	0	0	0	0	0	0	0	0	1	0	1	1	3
	000	000	000	000	000	000	000	000	010	000	100	100	2 1 0
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
	000	000	000	000	100	010	000	000	000	020	100	000	2 3 0
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
	000	000	000	000	000	000	000	010	000	010	010	000	0 3 0
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
	000	000	000	000	010	000	000	000	000	010	200	000	2 2 0
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
	000	000	000	000	020	000	000	000	000	020	010	010	0 6 0
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
	010	000	000	000	000	000	000	000	000	000	020	000	0 3 0
1987	0	1	0	0	0	2	0	0	0	2	1	2	8
	000	010	000	000	000	020	000	000	000	020	010	020	0 8 0
1988	0	0	0	0	0	1	0	0	0	1	2	1	5
	000	000	000	000	000	010	000	000	000	010	110	010	1 4 0
1989	0	0	0	0	1	1	0	0	0	0	1	0	3
	000	000	000	000	010	010	000	000	000	000	100	000	1 2 0
1990	0	0	0	1	1	0	0	0	0	0	1	1	4
	000	000	000	001	100	000	000	000	000	000	001	010	1 1 2
1991	1	0	0	1	0	1	0	0	0	0	1	0	4
	010	000	000	100	000	010	000	000	000	000	100	000	1 3 0
1992	0	0	0	0	1	2	1	0	1	3	3	2	13
	000	000	000	000	100	020	010	000	001	021	210	020	3 8 2
1993	0	0	0	0	0	0	0	0	0	0	2	0	2
	000	000	000	000	000	000	000	000	000	000	200	000	2 0 0
1994	0	0	1	1	0	1	0	0	0	1	1	0	5
	000	000	010	100	000	010	000	000	000	010	010	000	1 4 0
1995	0	0	0	0	0	0	0	0	1	1	2	0	4
	000	000	000	000	000	000	000	000	010	010	200	000	2 2 0
1996	0	0	0	0	1	3	0	0	0	2	2	0	8
	000	000	000	000	010	120	000	000	000	110	200	000	4 4 0
1997	0	0	0	0	1	0	0	0	1	1	1	0	4
	000	000	000	000	100	000	000	000	100	010	010	000	2 2 0

TABLE 3-6 DISTRIBUTION OF NORTHERN INDIAN OCEAN TROPICAL CYCLONES FOR 1975 - 1998													
1998	0	0	0	0	2	1	0	0	1	1	2	1	8
	000	000	000	000	110	100	000	000	010	010	200	100	5 3 0
(1975-1998)													
MEAN	0.1	0.1	0.1	0.2	0.6	0.6	0.1	0.1	0.3	0.9	1.4	0.6	5
													1.5 3.3 .3
CASES	3	0	0	4	14	13	1	1	8	24	32	13	121
													36 79 6

The criteria used in TABLE 3-6 are as follows:

1) If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.

2) If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

Tropical Depression 01W

The first 1998 Northwest Pacific Ocean tropical cyclone warned on by JTWC developed in the Philippine Sea. It intensified slowly, moved northwestward, then dissipated over Taiwan after 5 days.

Tropical Depression (TD) 01W formed approximately 600 nm east of Luzon. JTWC issued the first warning on TD 01W at 071500Z July. By 080600Z July, the cyclone had reached a maximum intensity of 30 kt. Subsequently, vertical wind shear resulted in TD 01W becoming an exposed low level circulation after 090000Z July.

TD 01W moved very slowly for the initial 48 hours, then began to accelerate northwestward on the 9th to about 11 kt just before striking the northern tip of Taiwan around 102100Z July. After landfall, the cyclone dissipated quickly. The final JTWC warning was issued at 110300Z July.

The primary significance of this cyclone was that it was the latest "start" of the Northwest Pacific Ocean tropical cyclone season as indicated by JTWC records (since 1959). This late season start appears to be directly related to the "La Nia" event of 1998.

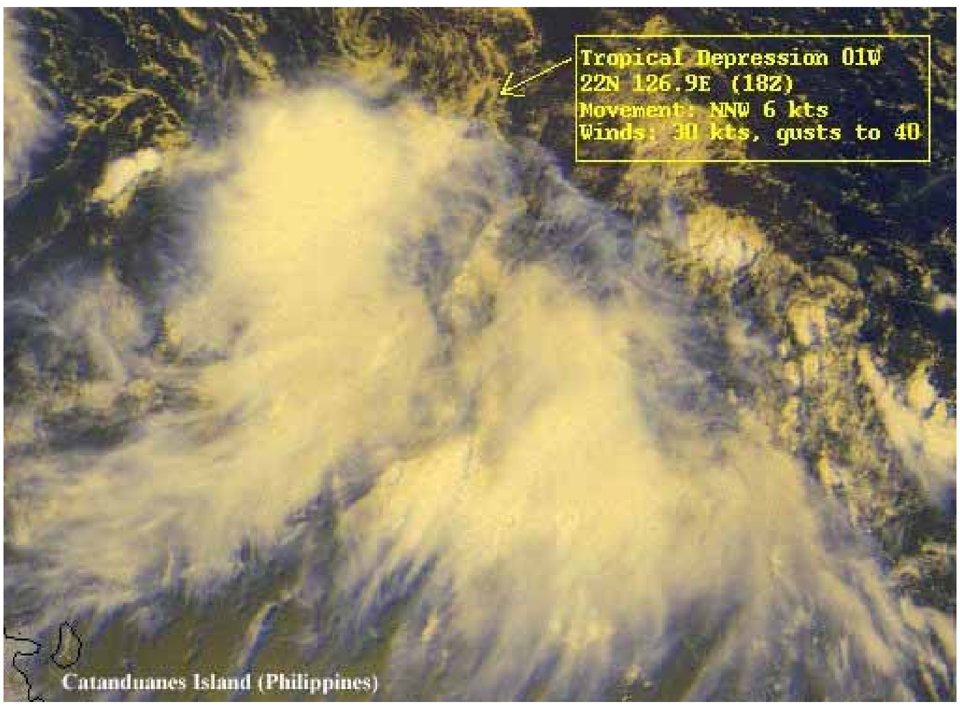
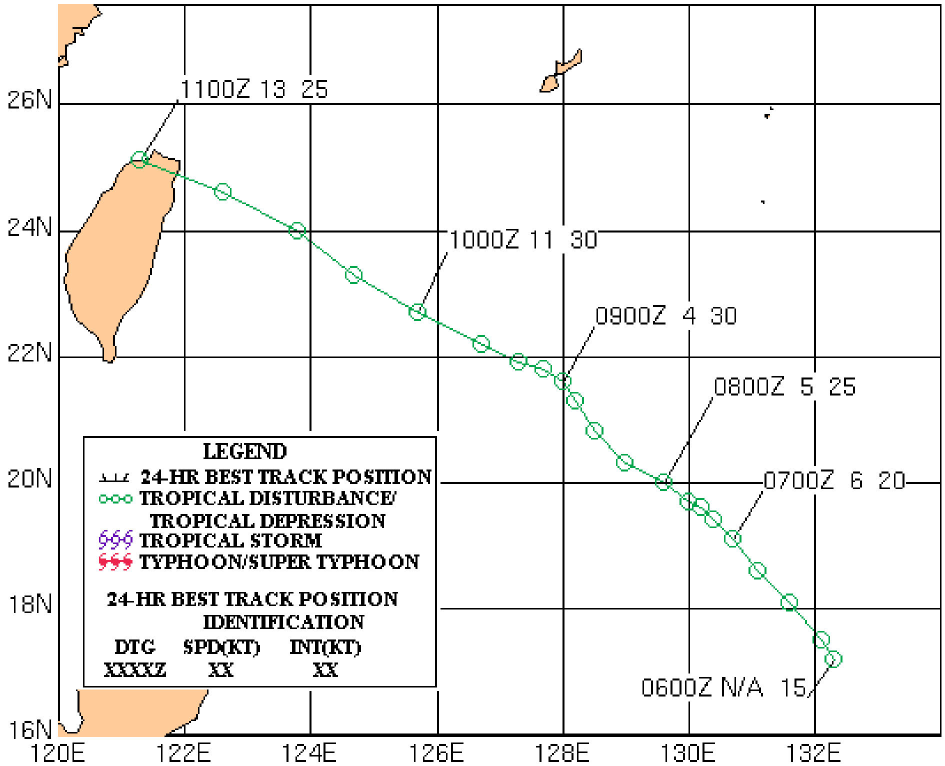


Figure 3-01-1. A NOAA multi-spectral image showing TD 01W as an exposed low-level circulation northeast of the Philippines.



26N
24N
22N
20N
18N
16N
120E
122E
124E
126E
128E
130E
132E
1100Z 13 25
1000Z 11 30
0900Z 4 30
0800Z 5 25
0700Z 6 20
0600Z N/A 15
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Tropical Storm Nichole (02W)

Tropical Storm (TS) Nichole (02W), was the second tropical cyclone and the first named storm of 1998. This cyclone formed in the South China Sea and reached a maximum intensity of 50 kt in the Taiwan Strait before making landfall and dissipating near Xiamen, China on the 12th of July.

JTWC issued a Tropical Cyclone Formation Alert at 071700Z July on a broad area of convection in the South China Sea. The first warning was issued at 080300Z July as a 25 kt cyclone. Subsequently, TS Nichole moved steadily north-northeastward at 6 to 8 kt. Due to constricted upper-level outflow to the north, it intensified slowly reaching tropical storm intensity at 081800Z July. TS Nichole achieved maximum intensity of 50 kt at approximately 091200Z July while just offshore of the southwest coast of Taiwan. Interaction with land and associated dry air entrainment, together with increased vertical shear, weakened the cyclone rapidly and TS Nichole became an exposed low level circulation. It moved westward and dissipated over southeastern China. The final warning was issued at 122100Z July.

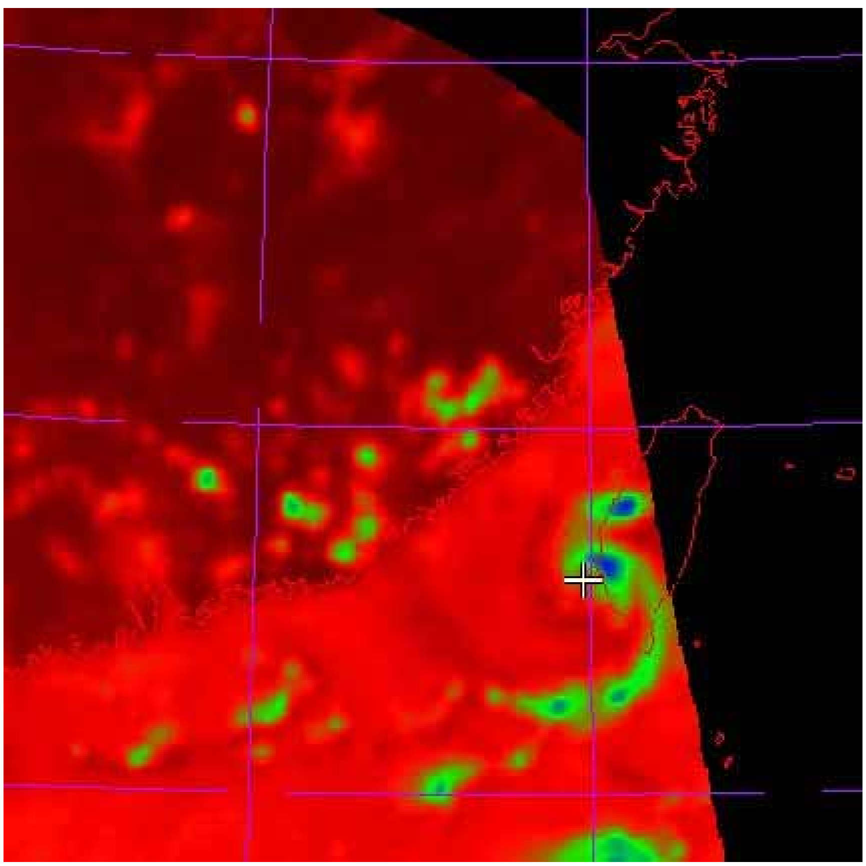
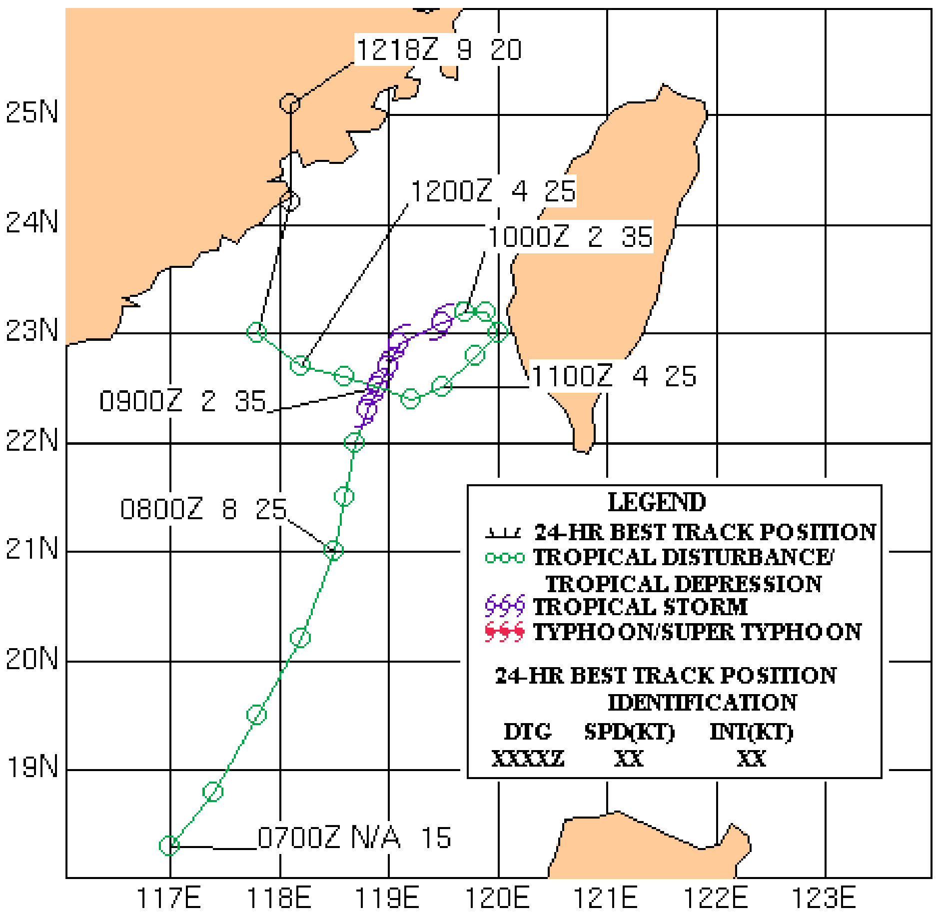


Figure 3-02-1. 090942Z July Special Sensor Microwave Imagery (SSM/I) depiction of TS Nichole at its maaximum intensity of 50 kt.



1218Z 9 20
1200Z 4 25
1000Z 2 35
1100Z 4 25
0900Z 2 35
0800Z 8 25
0700Z N/A 15
25N
24N
23N
22N
21N
20N
19N
117E
118E
119E
120E
121E
122E
123E
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG
SPD(KT)
INT(KT)
XXXXZ
XX
XX

Tropical Storm 03W

Tropical Storm (TS) 03W developed on the eastern periphery of a monsoon gyre 425 nm east-northeast of Iwo Jima on 25 July. Although JTWC never upgraded this cyclone to a tropical storm, post-analysis indicated a peak intensity of 45 kt. Hence, "No Name" was assigned.

JTWC first mentioned this disturbance on the 240600Z July Significant Tropical Weather Advisory (ABPW). No Tropical Cyclone Formation Alert was issued and JTWC issued the first warning at 250300Z July.

TS 03W moved cyclonically around the monsoon gyre for the first 24 hours, and intensified to 45 kt at 251200Z. As TS 03W tracked further north, it weakened as it encountered increased vertical windshear associated with the mid-latitude westerlies. TS 03W then turned northward and accelerated under the steering influence of the subtropical ridge to the southeast.

By 260533Z, vertical windshear had exposed the Low-Level Circulation Center. The final warning was issued at 260900Z July.

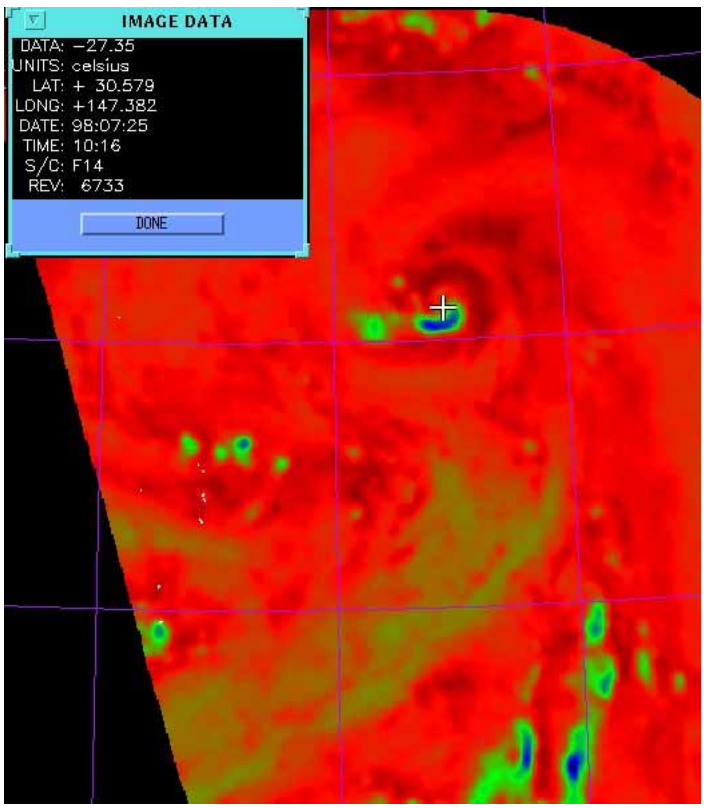


Figure 3-03-1. 25 Jul 98 1016Z SSM/I data which indicates convection wrapping into northeastern quadrant of the cyclone that supports a maximum intensity of 45 kt.

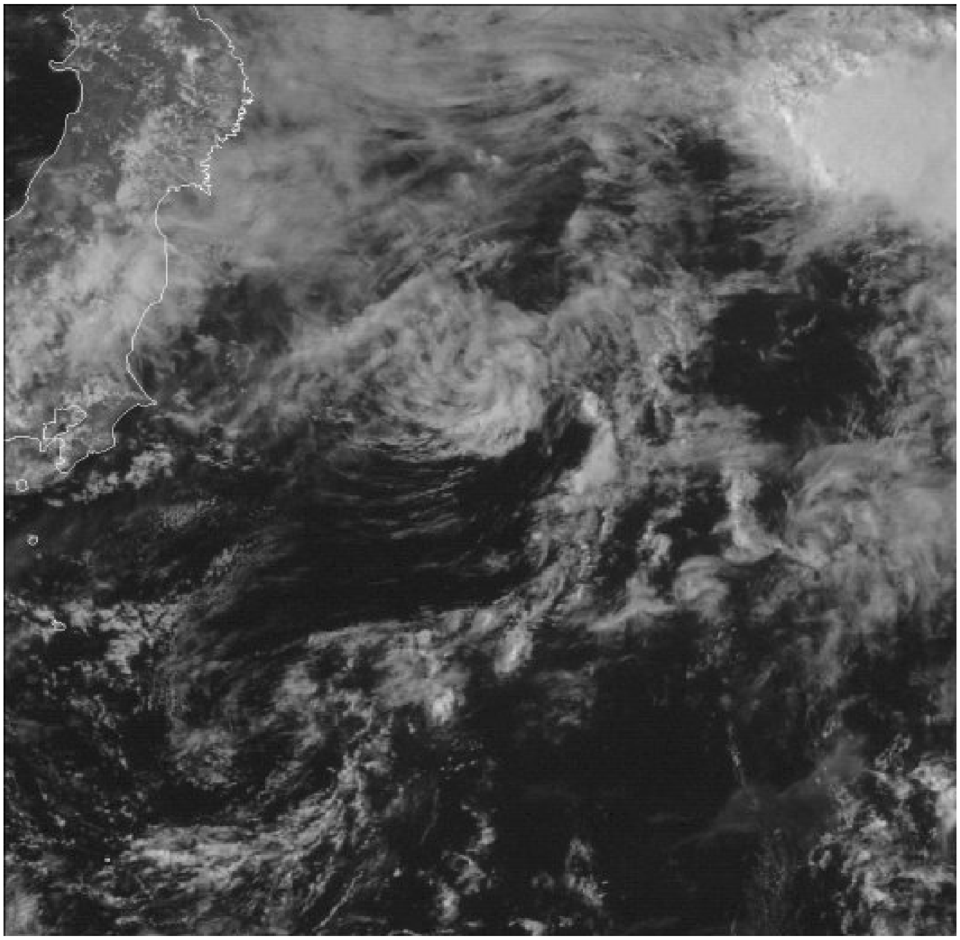
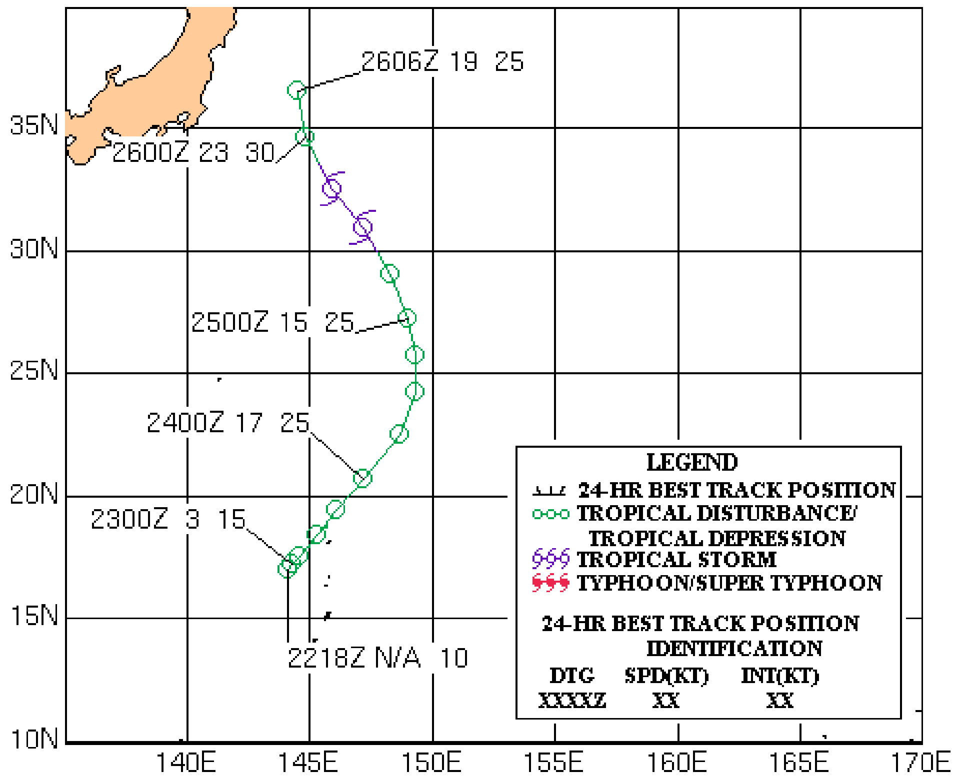


Figure 3-03-2. 260533Z July visible GMS image with TS 03W as an exposed LLCC.



2606Z 19 25
2600Z 23 30
2500Z 15 25
2400Z 17 25
2300Z 3 15
2218Z N/A 10
35N
30N
25N
20N
15N
10N
140E
145E
150E
155E
160E
165E
170E
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Typhoon Otto (04W)

Typhoon (TY) Otto (04W) formed over extremely warm ocean temperatures (¿ 30 degrees C) east of Luzon. This cyclone developed from a persistent mesoscale convective complex to a 100 kt typhoon during its relatively straight 4-day northwestward track. TY Otto tracked across Taiwan, then moved into southeastern China causing widespread flooding in Fukien Province.

Based on 011411Z August ERS-2 satellite scatterometer data and satellite imagery showing increased deep convection, JTWC issued the first warning at 020300Z August. Intensification to tropical storm occurred twelve hours later as the cyclone began to accelerate and move northwestward toward Taiwan in response to steering flow from the mid-tropospheric subtropical ridge. Minimal typhoon intensity was reached at 031200Z August.

TY Otto reached a maximum intensity of 100 kt on 040000Z August just prior to making landfall on the southeastern coast of Taiwan. The island's rugged, mountainous terrain temporarily lowered the cyclone's maximum sustained winds to 60 kt, but TY Otto reintensified to minimal typhoon intensity over the Taiwan Strait and continued to move northwestward. It then made a second landfall near the city of Fuzhou in southeastern China at 042000Z August, where the associated heavy rainfall contributed to widespread flooding in Fukien Province. Maximum sustained winds were estimated at 50 kt when JTWC issued its thirteenth and final warning at 050300Z August 1998.

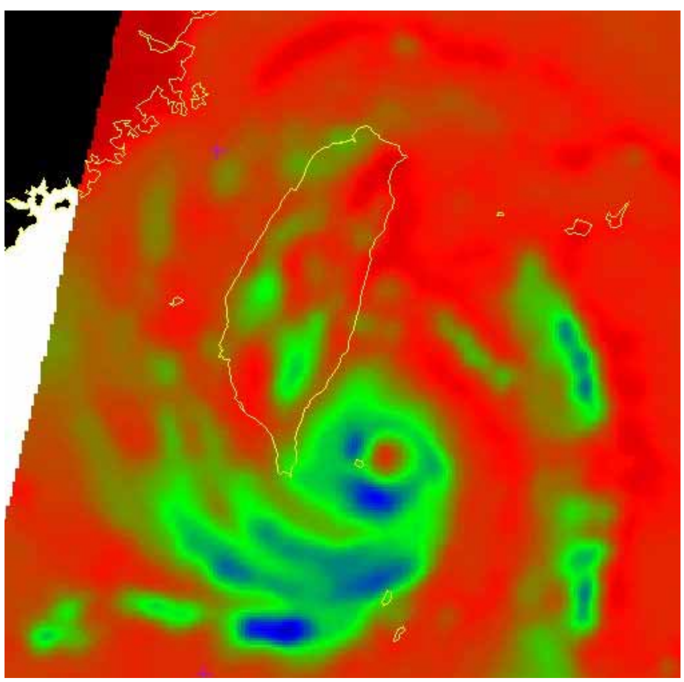


Figure 3-04-1. DMSP 040044Z August microwave image of Typhoon Otto just prior to landfall in southeastern Taiwan.

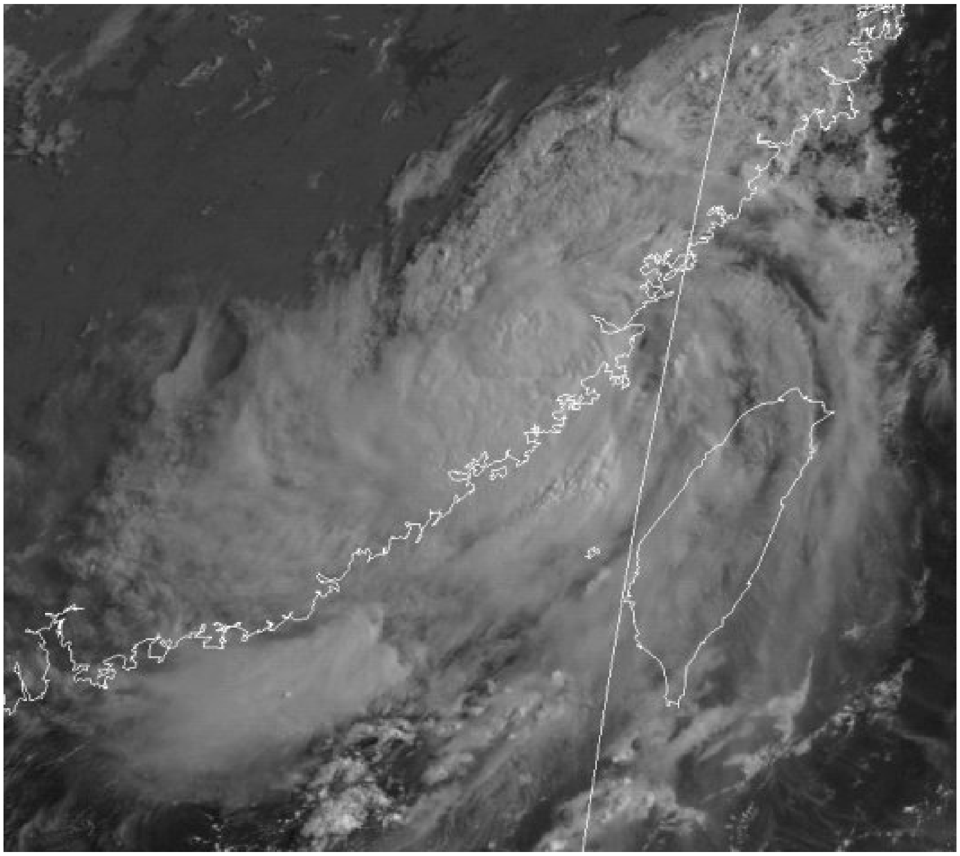
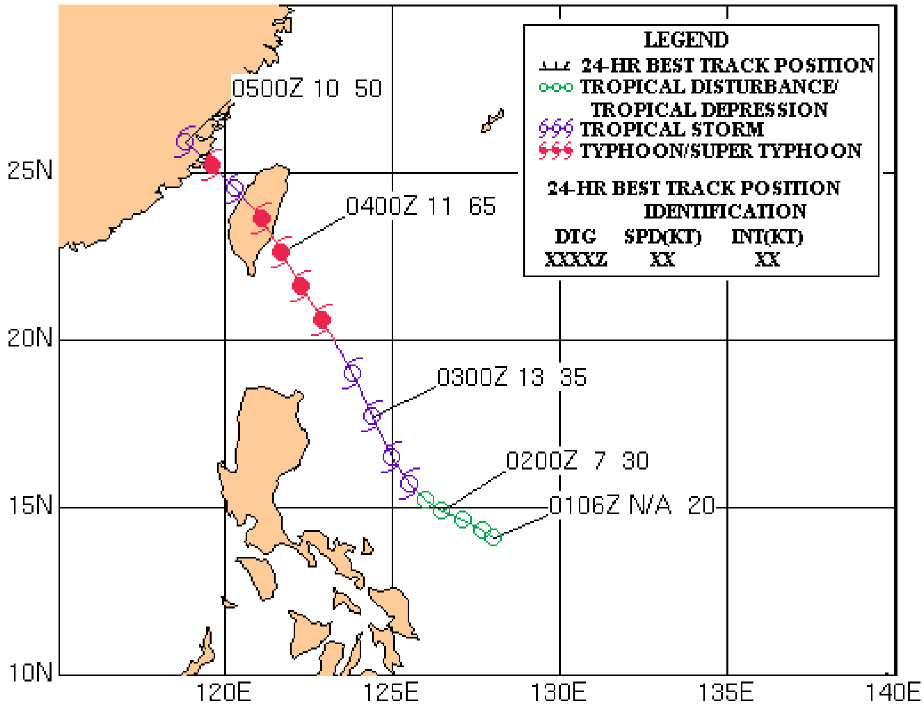


Figure 3-04-2. 050000Z August GMS-5 visible image of Typhoon Otto just after making landfall in southeastern China.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
0500Z 10 50
0400Z 11 65
0300Z 13 35
0200Z 7 30
0106Z N/A 20
25N
20N
15N
10N
120E
125E
130E
135E
140E

Tropical Storm Penny (05W)

Tropical Storm (TS) Penny (05W) formed in early August from a persistent mesoscale convective complex over the very warm Philippine Sea in the same manner as TY Otto (04W) the week prior. JTWC issued a Tropical Cyclone Formation Alert on 051900Z August as deep convection persisted and a surface cyclone began to develop. JTWC issued its first warning on TS Penny at 060900Z August with maximum sustained winds of 25 kt.

As with TY Otto (04W), the midtropospheric subtropical ridge was the primary steering influence for TS Penny (05W) during the cyclone's northwestward movement toward Luzon Island and subsequent passage across the South China Sea and into southern China.

It took 36 hours for the tropical depression to reach tropical storm intensity. This intensification occurred at 071200Z August, just prior to the cyclone making landfall over northern Luzon. Interaction with mountainous terrain temporarily weakened TS Penny to tropical depression strength but, after 18 hours, the cyclone reintensified to tropical storm strength and reached a maximum intensity of 60 kt during its South China Sea passage.

TS Penny made a second landfall in southern China near Zhanjiang at approximately 110000Z August, where associated heavy rainfall contributed to widespread flooding. Maximum sustained winds were estimated at 35 kt when JTWC issued its eighteenth and final warning at 110900Z August.

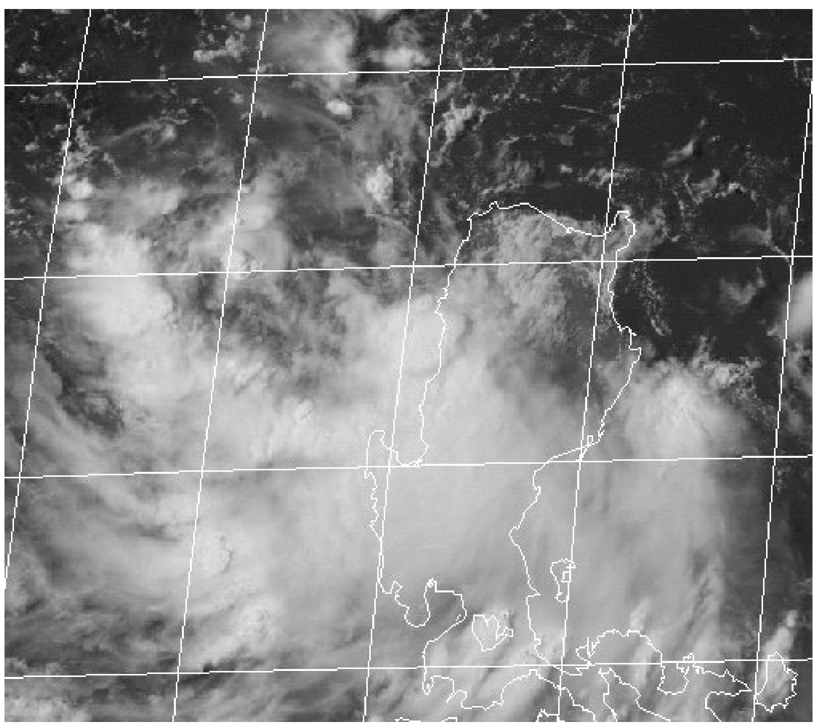


Figure 3-05-1. 080700Z August GMS-5 visible image of TS Penny crossing Luzon.

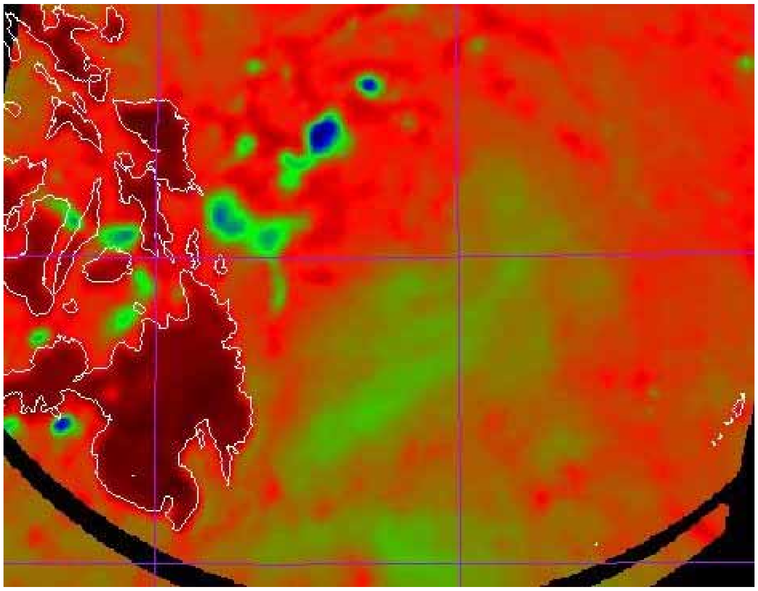
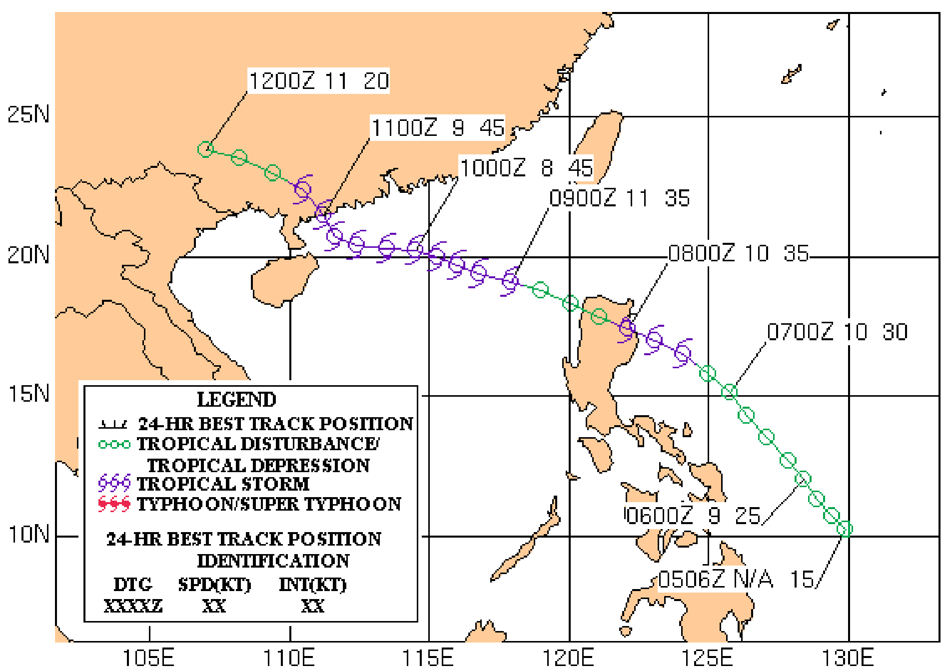


Figure 3-05-2. 060019Z August DMSP microwaveimage of TS Penny during its formative stages.



Typhoon Rex (06W)

The paramount forecasting challenge of the 1998 Northwest Pacific tropical cyclone season was Typhoon (TY) Rex (06W). This cyclone formed in the Philippine Sea and was influenced by synoptic features present in the mid and upper troposphere during its meander northeastward. The influence of 3 distinct TUTT cells caused TY Rex's track to deviate from its forecasted northeast track 3 separate times. Seventeen days after initial detection, TY Rex (06W) transitioned to an extratropical cyclone southeast of the Kamchatka Peninsula.

TY Rex (06W) formed in a broad trough east of Luzon late in August, 1998 and was first described as a suspect area on the 210600Z August JTWC Significant Tropical Weather Advisory. The first warning was issued at 240300Z August. The cyclone continued to steadily intensify as it tracked northeastward at 8 kt in response to flow emanating from the mid-tropospheric subtropical ridge to the east. On 260000Z August, TY Rex was designated a typhoon with a maximum intensity of 70 kt with an associated eastward track change noted at around the same time.

The Tropical Upper Tropospheric Trough (TUTT) was very active in August and "cells" or cyclones within this trough affected the track and intensity of Typhoon Rex. The first TUTT cell weakened the subtropical ridge to the east, allowing TY Rex to track eastward from 251200Z to 270000Z August. As the influence of the TUTT cell waned, TY Rex resumed a more northward course and reached peak intensity of 115 kt with a 30 nm diameter eye at 280600Z August. TY Rex began to move northward toward Honshu when a second, much deeper TUTT cell began to weaken the subtropical ridge to the east. In response, TY Rex again began to move east-southeastward around 310600Z August. During this period, TY Rex weakened to 90 kt and later intensified to a 100 kt cyclone at 010000Z September.

After the second TUTT cell began to move westward, TY Rex resumed its northeastward track on 020600Z September. After passing, north of 30 degrees north, TY Rex began weakening due to cooler surface waters and increased vertical wind shear. Around 031200Z September, a third TUTT cell began to interact with TY Rex, causing an eastward jaunt for approximately 18 hours. This TUTT cell, however, was the weakest of the three and rapidly collapsed, allowing Rex to resume its northeastward movement by 041200Z September.

Between 4th and 7th of September, Typhoon Rex continued to track northeastward and then eastward while transitioning into an extratropical system. JTWC issued the final warning on this cyclone at 070300Z September.

Although Rex never made landfall, its proximity to Honshu, Japan caused heavy flooding and 575 mudslides. The media reported 13 fatalities, 30 injuries, and 8,000 homes destroyed.

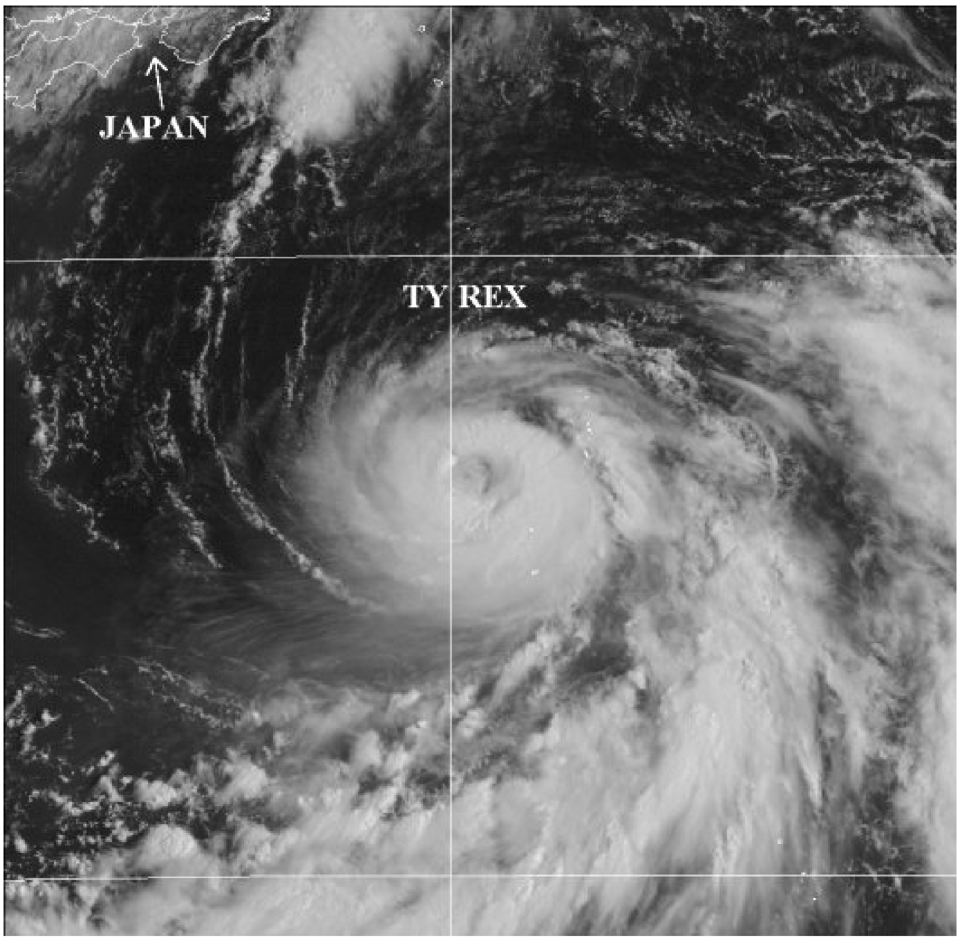


Figure 3-06-1. Visible satellite data of TY Rex at 272334Z August, 1998 when the cyclone was a 110 kt system and about 6 hours away from peak intensity of 115 kt.

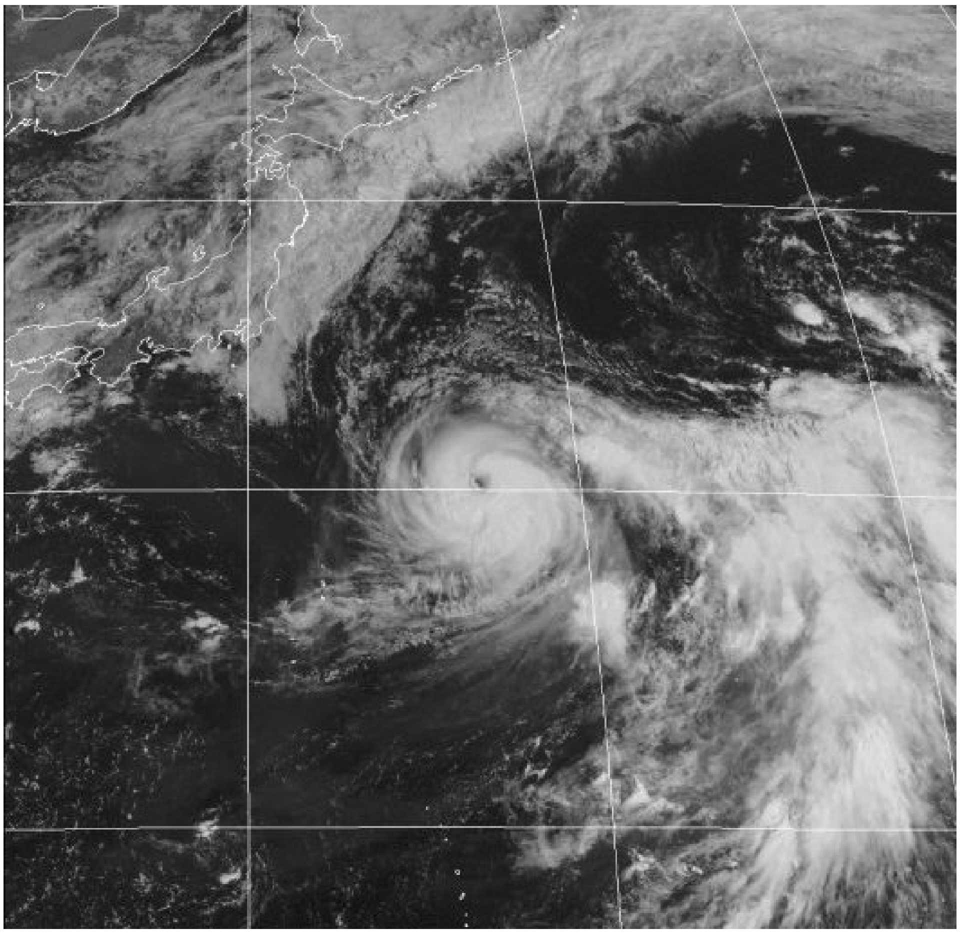
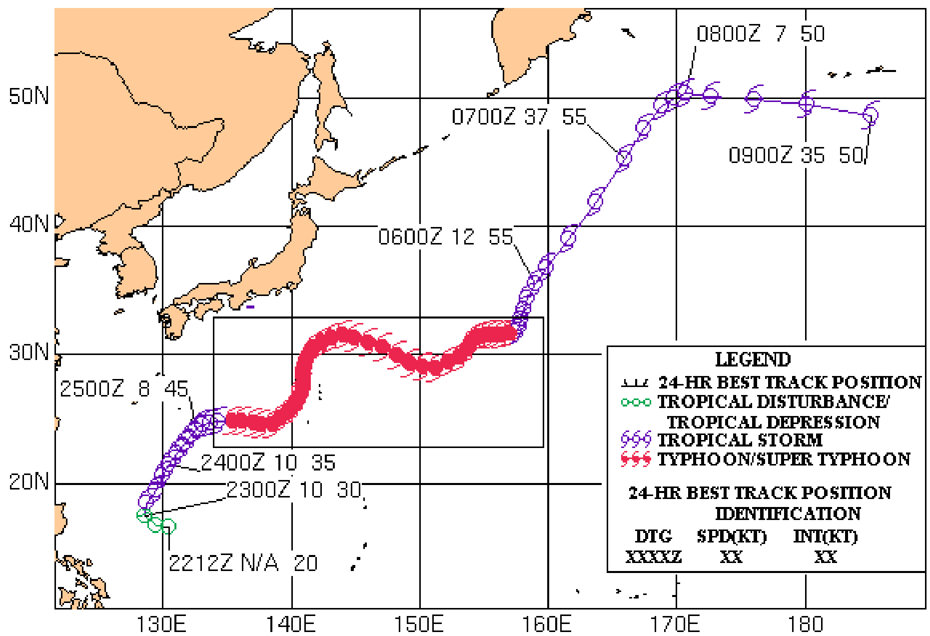
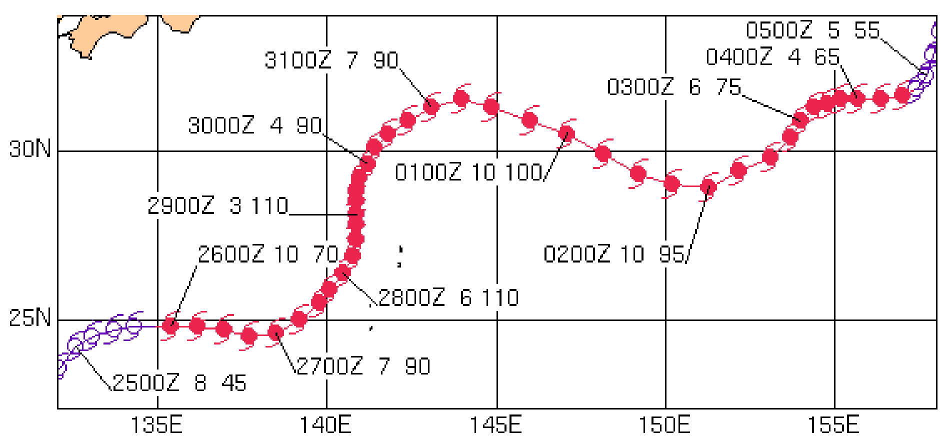


Figure 3-06-2. Visible satellite image of TY Rex at 312334Z August, 1998 undergoing reintensification to a 100 kt cyclone after weakening to 90 kt.


50N
40N
30N
20N
130E
140E
150E
160E
170E
180
0800Z 7 50
0700Z 37 55
0900Z 35 50
0600Z 12 55
2500Z 8 45
2400Z 10 35
2300Z 10 30
2212Z N/A 20
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX


30N
25N
135E
140E
145E
150E
155E
0500Z 5 55
0400Z 4 65
0300Z 6 75
3100Z 7 90
3000Z 4 90
0100Z 10 100
2900Z 3 110
2600Z 10 70
0200Z 10 95
2800Z 6 110
2700Z 7 90
2500Z 8 45

Tropical Depression 07W

Tropical Depression (TD) 07W developed east of Taiwan along the trailing edge of a stationary front. The first warning was issued on 020900Z September as a 30 kt system. Although convection did periodically increase, this Depression failed to intensify.

After forming just east of Taiwan, TD 07W tracked rapidly northeastward under the steering influence of the 700mb subtropical ridge to the south. The system began to accelerate and turned more east-northeastward as moderate vertical shear began to displace the cyclone's convection away from the low-level circulation center. TD 07W slowed on 040000Z September, and vertical wind shear increased, caused by the outflow of nearby Typhoon Rex (06W). TD 07W dissipated over water, with the final warning issued on 040900Z September.

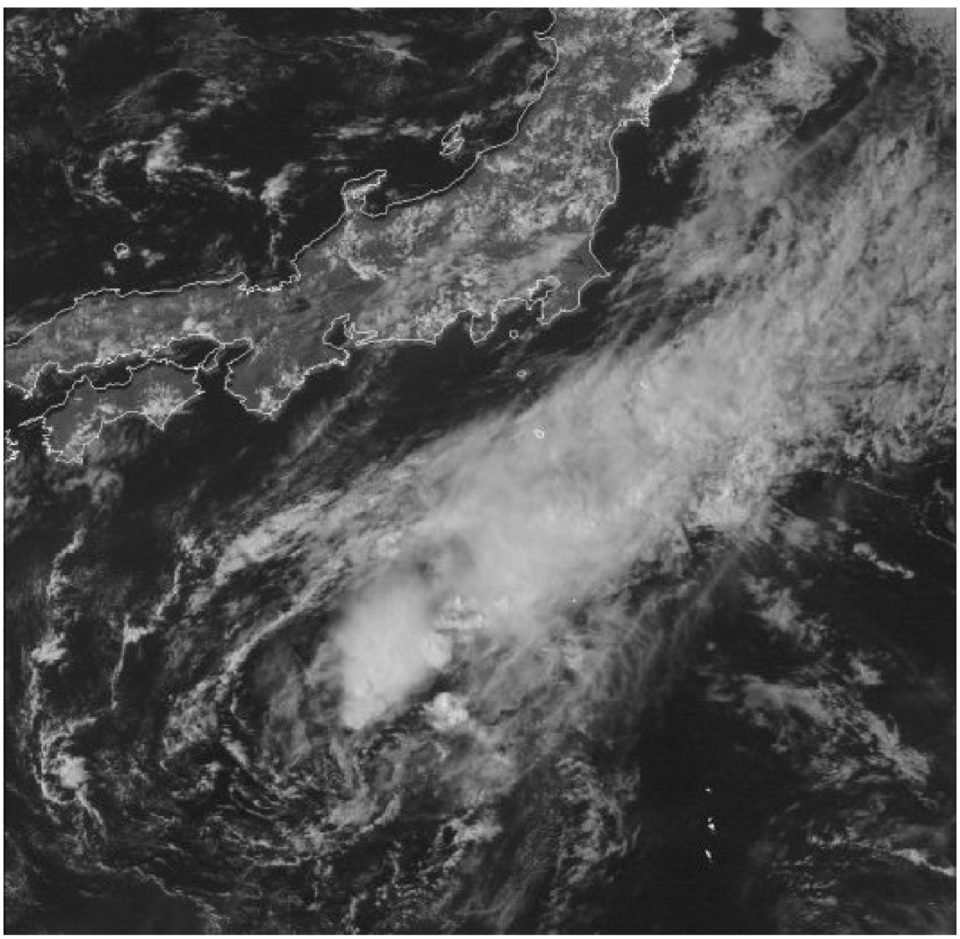
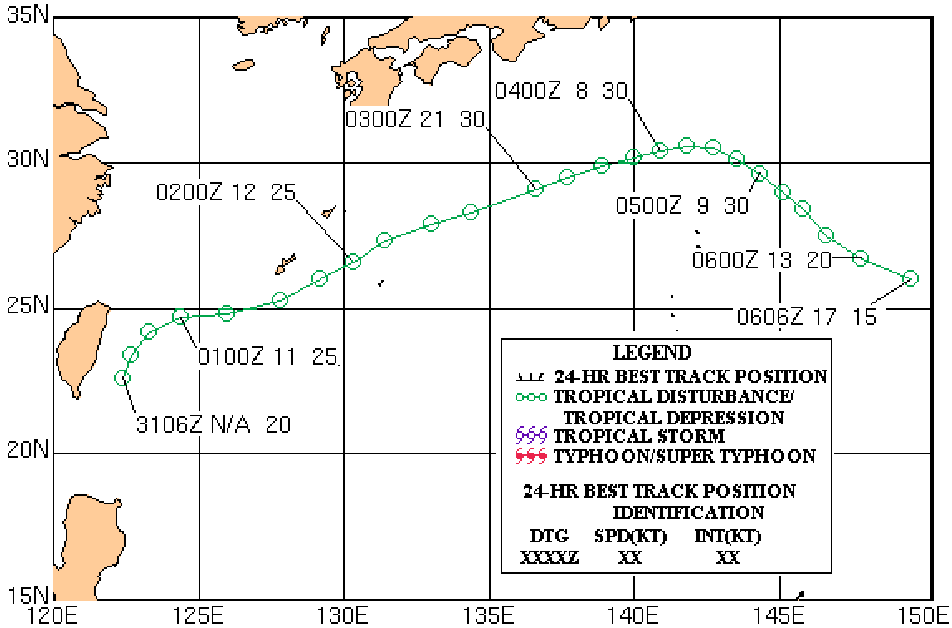


Figure 3-07-1. GMS-5 visible image of TD 07W at 030534Z September. Convection is being sheared to the northeast.


35N
30N
25N
20N
15N
120E
125E
130E
135E
140E
145E
150E
0400Z 8 30
0300Z 21 30
0200Z 12 25
0500Z 9 30
0600Z 13 20
0606Z 17 15
0100Z 11 25
3106Z N/A 20
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Typhoon Stella (08W)

Typhoon Stella (08W) began as a weak tropical disturbance just east of the northern Marianas Islands. The first warning was issued on 120900Z September as a tropical depression. The cyclone tracked northwestward for two days before reaching peak intensity and curving northeastward. This northeast turn took TY Stella along the eastern Honshu coast as it accelerated and became extratropical.

JTWC first mentioned this disturbance at 110600Z September on the Significant Tropical Weather Advisory. At 120000Z September, the disturbance was upgraded to a Tropical Cyclone Formation Alert. The first warning was issued at 120900Z September. TY Stella developed in the eastern portion of the monsoon trough, south of the subtropical ridge and tracked northwestward. TY Stella reached typhoon intensity as it moved into a weakness in the ridge and began transitioning into a poleward-oriented, steering pattern at 151200Z September. TY Stella tracked northeastward and continued to accelerate as it began to be influenced by the mid-latitude westerlies. TY Stella made landfall about 151800Z September near Numazu, Japan at minimum typhoon intensity. TY Stella became extratropical (XT) at 161200Z September. Once it became XT, it accelerated to 58 kt while maintaining an intensity of 60 kt. JTWC issued 18 warnings, with the final warning issued on 161500Z September.

CNN Tokyo (CNN, 17 Sep 1998) reported huge waves (23 feet), floods, heavy rains (14 inches in 24 hours), landslides, and four deaths.

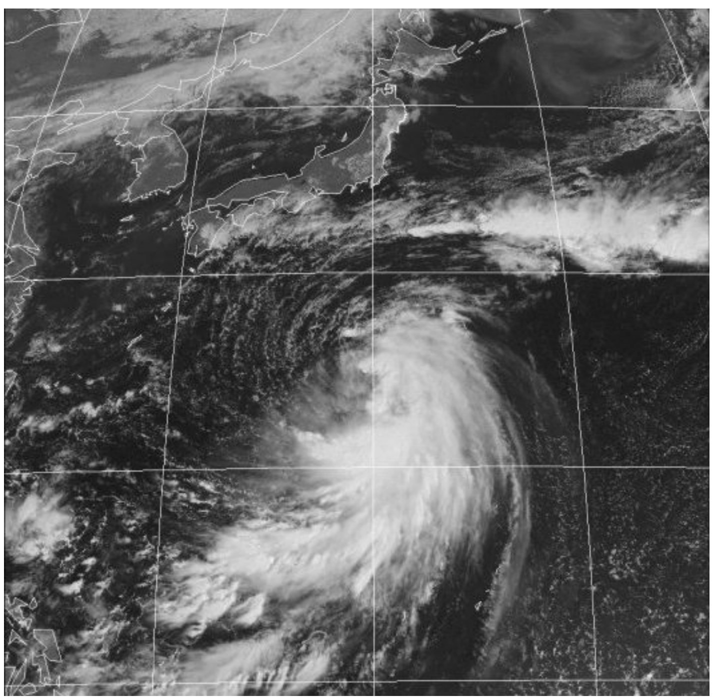
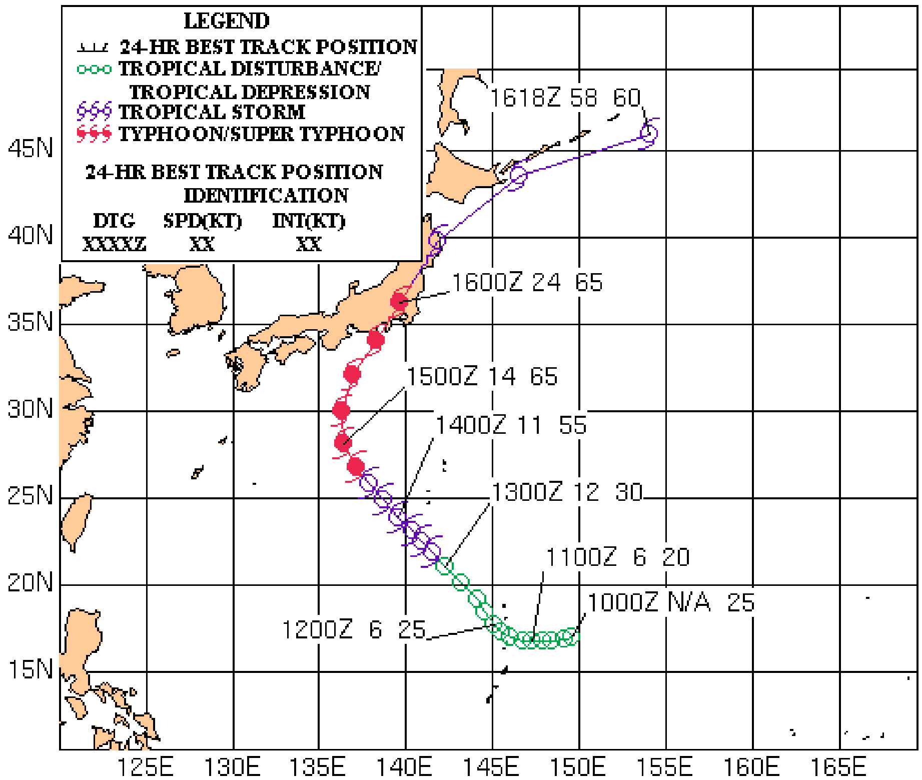


Figure 3-08-1. GMS-5 140034Z September visible image of Tropical Storm Stella (60 kt).



LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
1618Z 58 60
1600Z 24 65
1500Z 14 65
1400Z 11 55
1300Z 12 30
1100Z 6 20
1000Z N/A 25
1200Z 6 25
45N
40N
35N
30N
25N
20N
15N
125E
130E
135E
140E
145E
150E
155E
160E
165E

Tropical Depression 09W

Tropical Depression (TD) 09W developed in the monsoon trough east of Hainan Island in the South China Sea on 13 September. TD 09W was a short-lived, minimum intensity tropical depression.

JTWC first mentioned this disturbance on 120600Z September on the Significant Tropical Weather Advisory (ABPW). JTWC issued the first warning on 130900Z September. TD 09W developed within the monsoon trough about 250nm east of Hainan Do, China. TD 09W, south of the subtropical ridge, tracked westward at 10-15 kt with the low-level steering flow. TD 09W reached a maximum intensity of 25 kt as it moved through the Hainan Strait Channel, into the Gulf of Tonkin. It made landfall and dissipated over Vietnam. JTWC issued three warnings. The final warning was issued at 132100Z September.

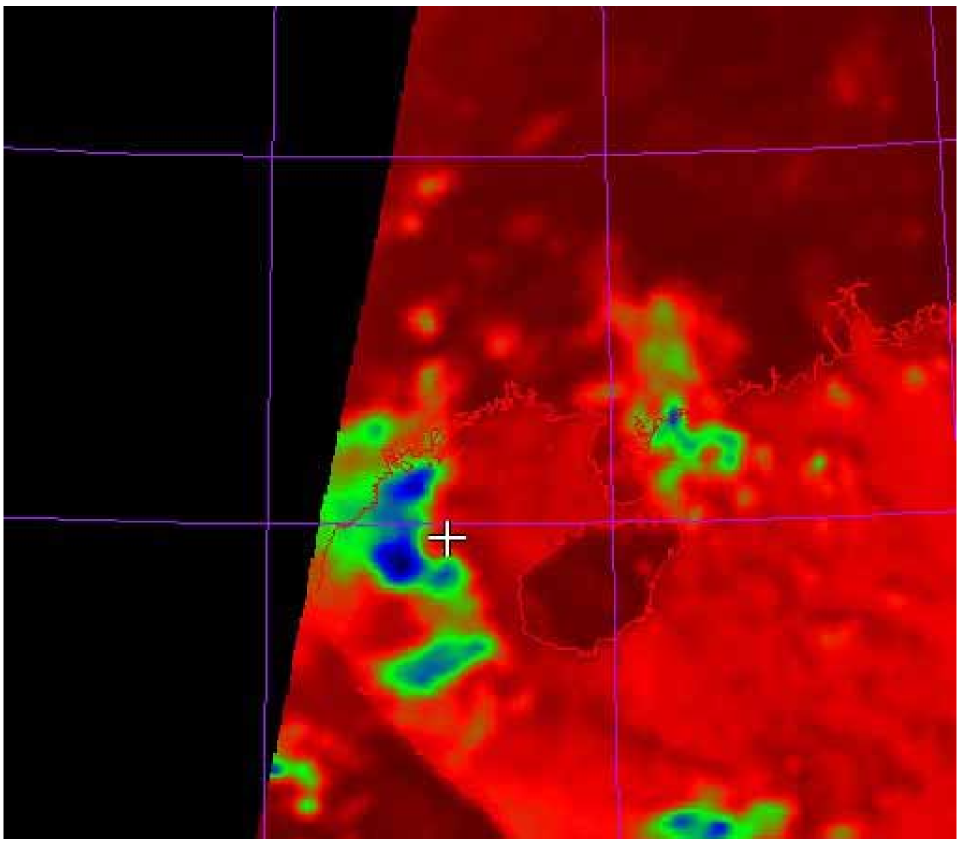
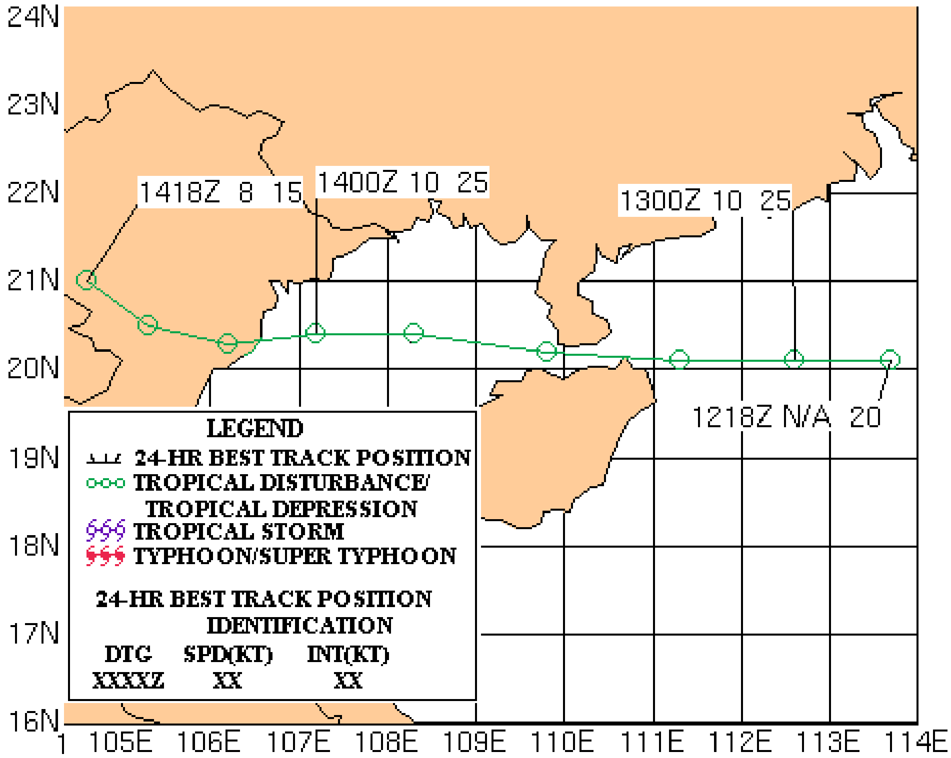


Figure 3-09-1. 132227Z September SSM/I pass. Convection is limited to west side of TD 09W. Low-level center is about 45 nm north of cursor location.


24N
23N
22N
21N
20N
19N
18N
17N
16N
1418Z 8 15
1400Z 10 25
1300Z 10 25
1218Z N/A 20
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
1 105E 106E 107E 108E 109E 110E 111E 112E 113E 114E

Super Typhoon Todd (10W)

Super Typhoon (STY) Todd (10W) formed in the Philippine Sea within a reverse oriented monsoon trough. Initially detected in mid September, STY Todd (10W) developed rapidly while moving cyclonically in response to mid-tropospheric steering flow and the influence of a monsoon gyre located in the South China Sea. STY Todd (10W) attained a maximum intensity of 130 kt then dissipated in the East China Sea 6 days after initial formation.

JTWC issued a Tropical Cyclone Formation Alert at 150900Z September. The disturbance was embedded in a large area of deep convection, which masked its initial intensification. JTWC issued the first warning with a maximum intensity of 45 kt at 160300Z September. This initial warning forecast northeast movement and typhoon intensity at 48 hours. However, by 170600Z September, STY Todd had reached its peak intensity of 130 kt with an observed 12 nm diameter cloud-filled eye while moving northeastward at 11 kt.

Between 170000Z and 180000Z STY Todd began to change direction and accelerate in response to the steering flow of a developing anticyclone over Kyushu and a monsoon gyre in the South China Sea. As a result, STY Todd attained a maximum speed of movement of 30 kt between 171800Z and 180000Z September.

After 171200Z September, STY Todd experienced increased vertical wind shear, weakening and moving westward. When STY Todd made landfall on the east coast of China, 85 nm south of Shanghai, it had weakened to a 55 kt system and continued to weaken as it moved westward over land. After 200000Z September, however, the cyclone reversed course and the exposed low-level circulation turned eastward and tracked into the East China Sea. The remnants of STY Todd became quasi-stationary and dissipated. JTWC issued its final warning at 200300Z September.

Although Kyushu did not experience passage of the cyclone center, heavy rains from STY Todd caused seven fatalities from flooding and mudslides. No reports of fatalities or damage in China were available at the time of this report.

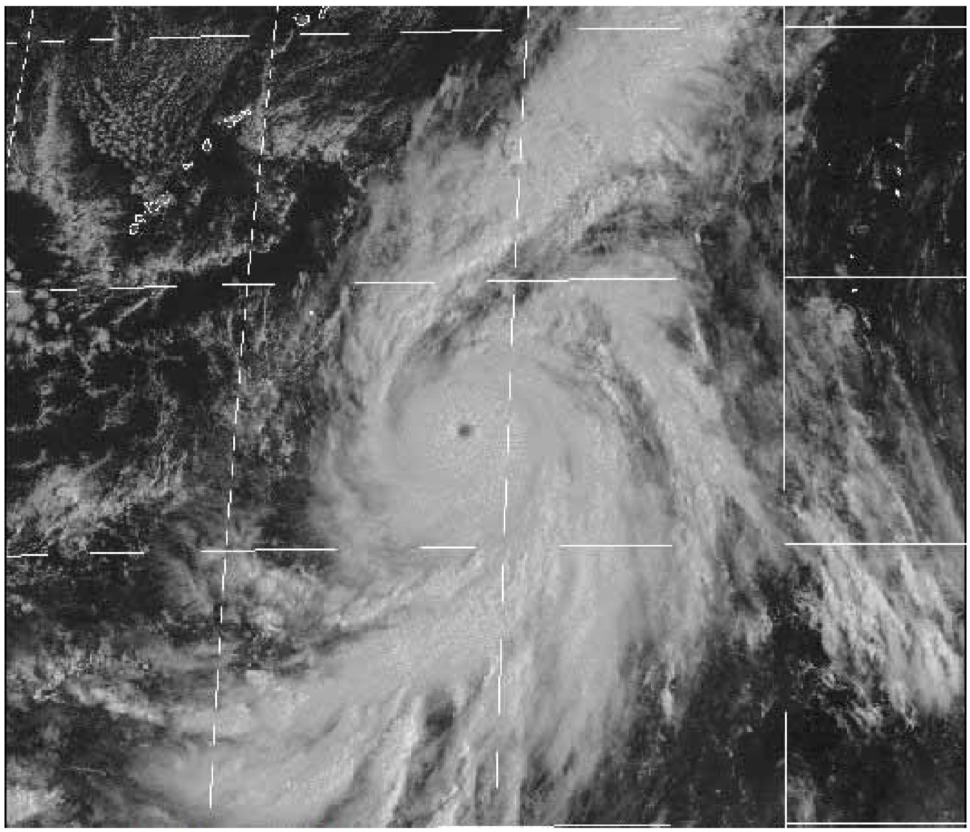


Figure 3-10-1. Visual Satellite image of Typhoon Todd at 2334Z on the 16th of September. At this point, TY Todd is a 120 kt system and will reach its maximum intensity of 130 kt within a few hours.

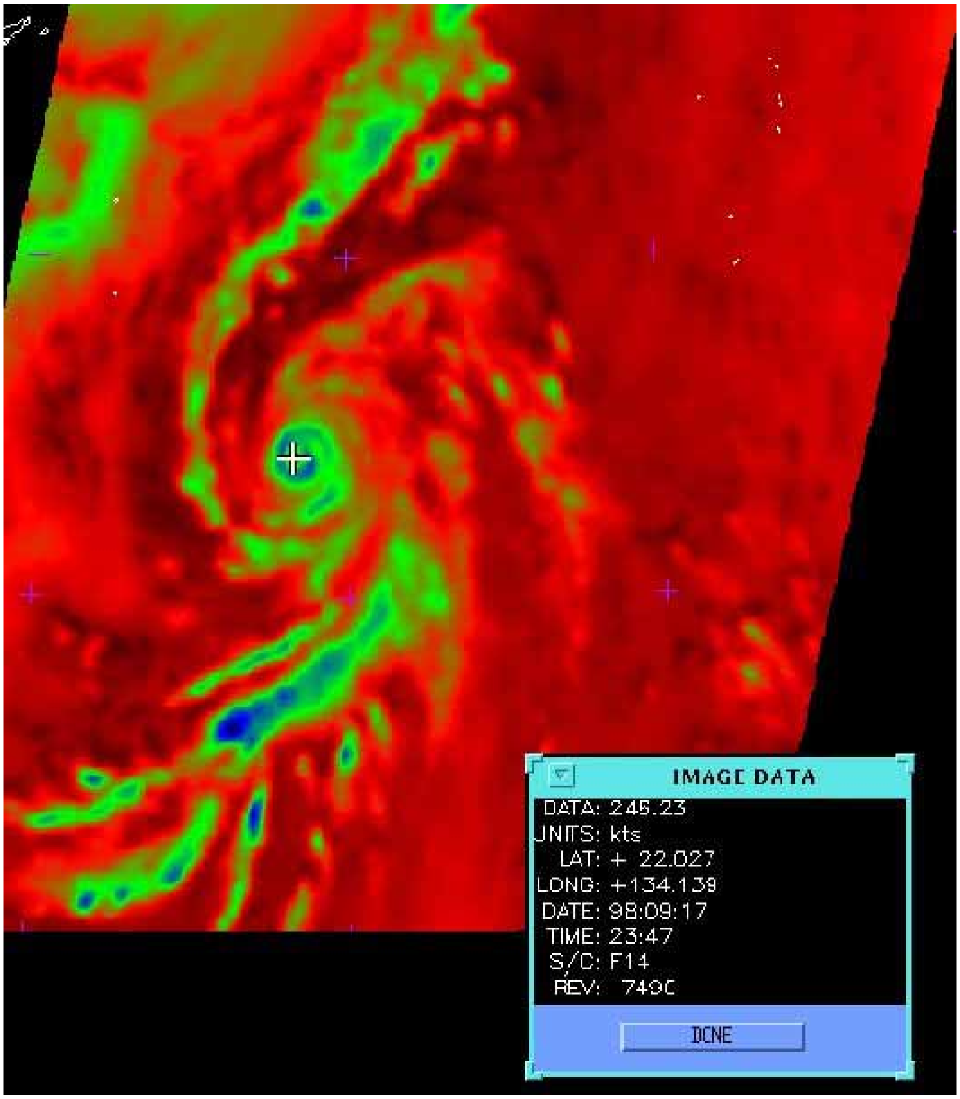


Figure 3-10-2. 172347Z September Special Sensor Microwave Image of STY Todd as an 80 kt system.

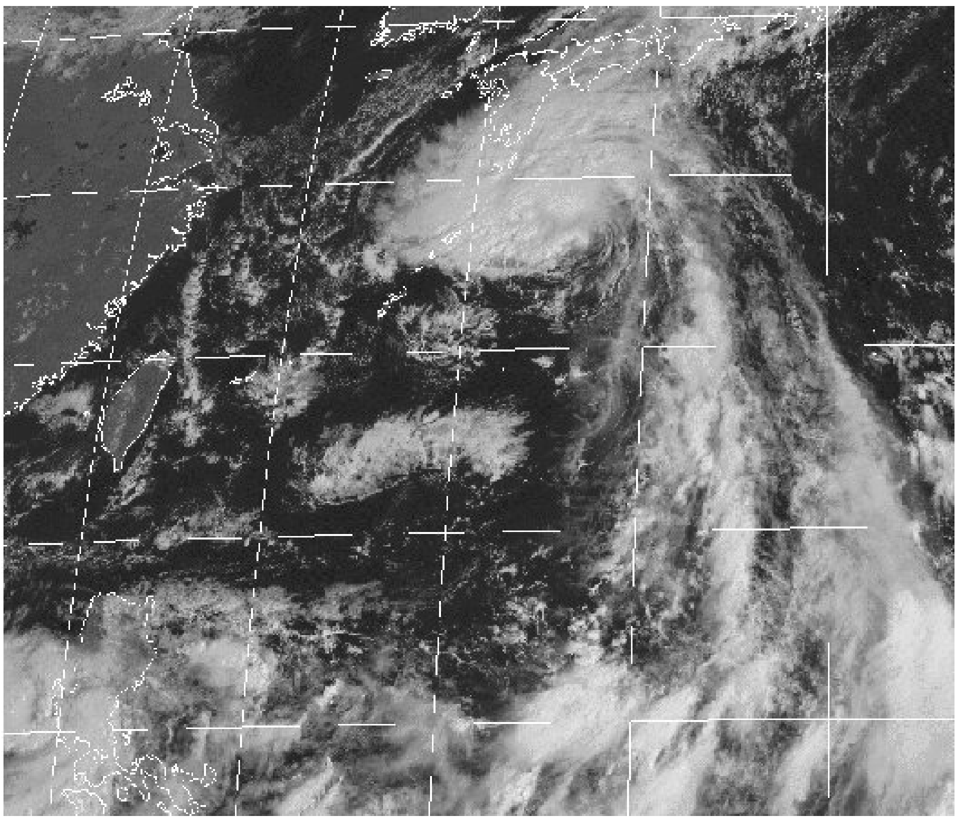
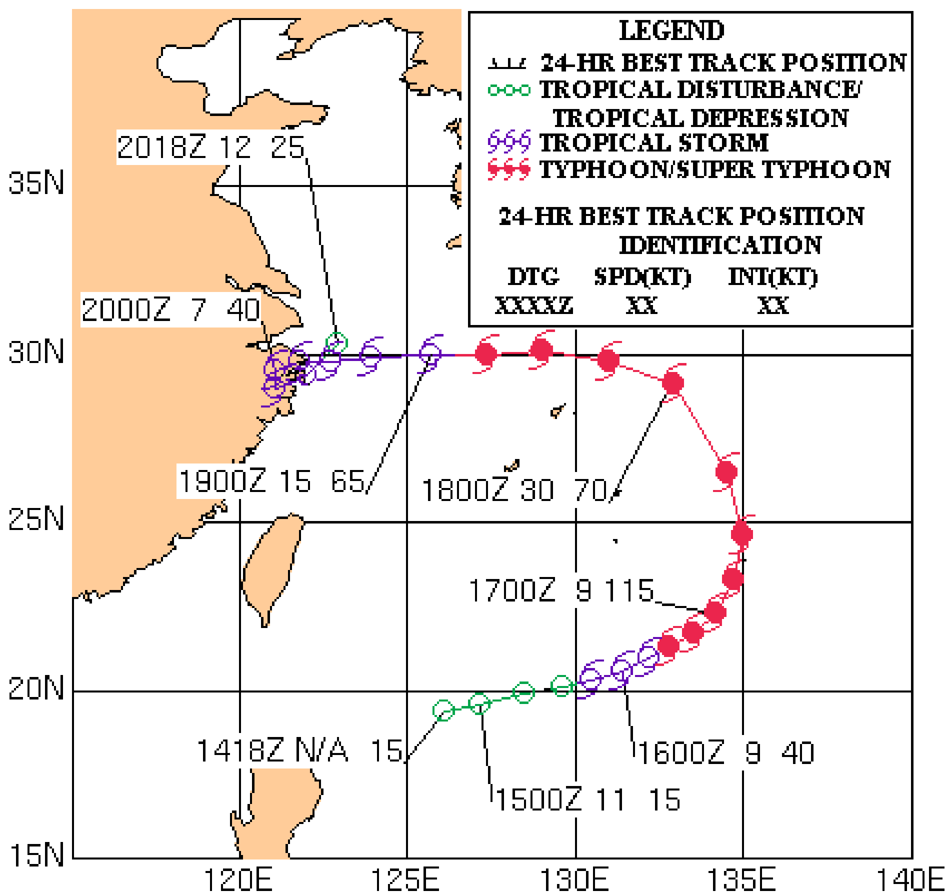


Figure 3-10-3. Visible imagery indicating STY Todd is experiencing vertical wind shear as shown by the partially exposed low level circulation. Application of the Dvorak Technique indicates STY Todd (10W) has a maximum intensity of 80 kt at this time.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/ TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
2018Z 12 25
2000Z 7 40
1900Z 15 65
1800Z 30 70
1700Z 9 115
1600Z 9 40
1500Z 11 15
1418Z N/A 15
35N
30N
25N
20N
15N
120E
125E
130E
135E
140E

Typhoon Vicki (11W)

TY Vicki (11W) developed in the South China Sea and moved eastward, reaching typhoon intensity before crossing Luzon. After passage into the Philippine Sea, the cyclone re-intensified and re-attained typhoon intensity east of Okinawa. TY Vicki continued its northeastward track over Shikoku and Honshu before becoming an extratropical cyclone.

JTWC issued a Tropical Cyclone Formation Alert at 160530Z September for an area of persistent convection with an associated low-level circulation center. The first warning was issued at 170300Z September as a 30 kt tropical depression.

TY Vicki (11W) began tracking slowly toward the east-southeast under the steering influence of the 700mb subtropical ridge to the south. The system intensified while approaching the west coast of Luzon. TY Vicki reached tropical storm strength by the 171200Z warning, and typhoon strength by the 180600Z warning. TY Vicki made its first landfall over western Luzon as an 85 kt typhoon and began tracking under the steering influence of the building mid-level subtropical ridge to the east. TY Vicki weakened to a 40 kt system due to interaction with land.

Once over open water, Typhoon Vicki began accelerating northeastward while slowly re-intensifying to typhoon strength by the 210000Z September warning. TY Vicki remained in a favorable environment while tracking at 16 to 27 kt toward Shikoku and Honshu in southwestern Japan. This strong steering flow was caused by the subtropical ridge to the east of the system and an approaching mid-latitude trough to the northwest. TY Vicki made its second landfall between 220000Z and 220600Z south of Osaka, Japan, as a 90 kt system. The system began weakening over land as it continued to accelerate within the strong westerly flow over central Japan. TY Vicki began to undergo extratropical transition as the mid-latitude interaction increased. The system became fully extratropical and the final warning was issued on 230300Z September.

CNN reported (19 September) that TY Vicki moved over Luzon killing 9 people and affected more than 300,000 people with severe flooding and a landslide that forced hundreds of people from their homes in several villages near Manila, Philippines. On 18 September, the ferry "Princess of the Orient" sank near the mouth of Manila Bay as it was heading for the city of Cebu. Dozens perished as the ferry sank with 430 people onboard. On 22 September, TY Vicki made a second landfall about 300 miles southwest of Tokyo, disrupting train and passenger service and canceling over 60 domestic flights in Japan.

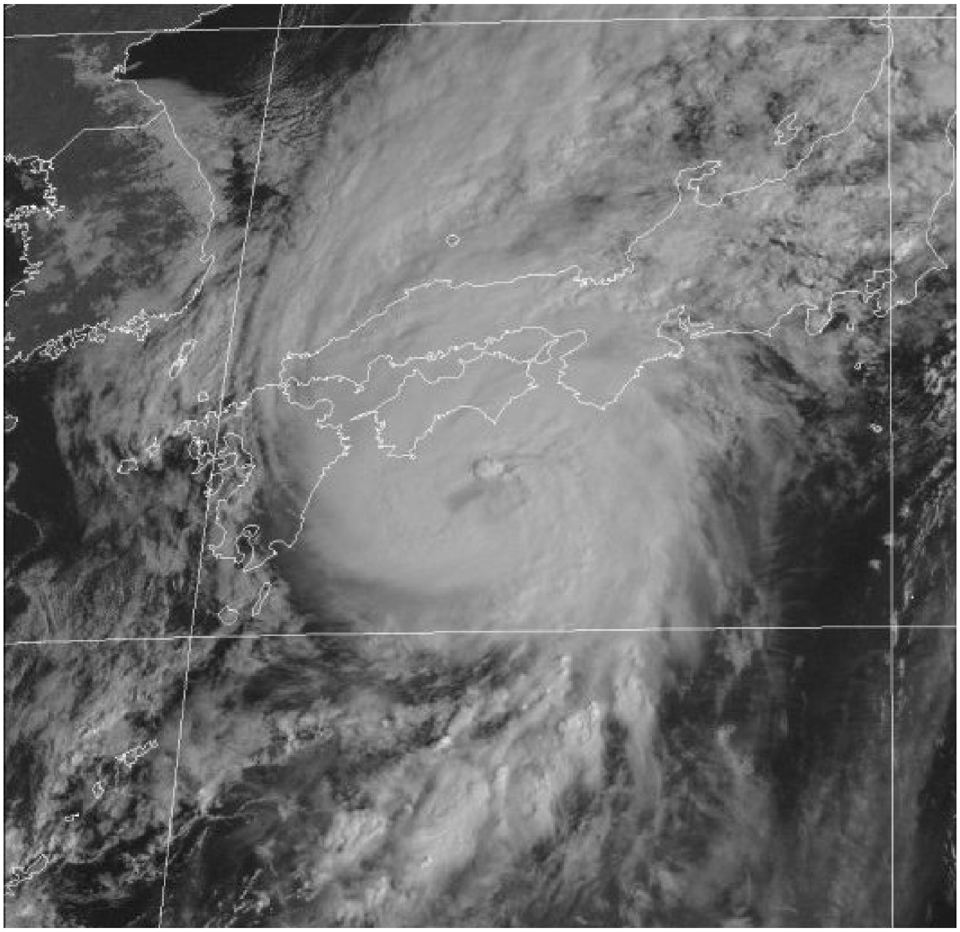
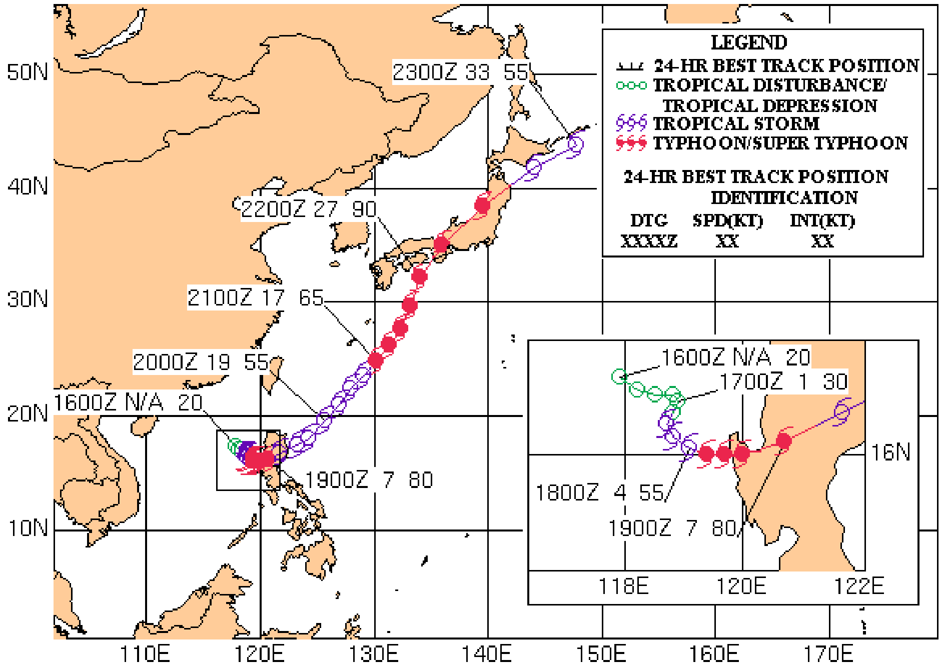


Figure 3-11-1. GMS-5 visible image of Typhoon Vicki (11W) at peak intensity (90 kt).


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
2300Z 33 55
2200Z 27 90
2100Z 17 65
2000Z 19 55
1600Z N/A 20
1900Z 7 80
1600Z N/A 20
1700Z 1 30
1800Z 4 55
1900Z 7 80
16N
118E
120E
122E
50N
40N
30N
20N
10N
110E
120E
130E
140E
150E
160E
170E

Tropical Depression 12W

Tropical Depression (TD) 12W formed in the South China Sea on 18 September, then moved northwest and made landfall in Vietnam 36 hours later. It remained a poorly organized system, reaching a maximum intensity of 30 kt while 30 nm off the Vietnamese coast.

JTWC first mentioned this monsoon trough disturbance located off the Vietnam coast in the 170600Z September Significant Tropical Weather Advisory. On 171100Z September, a Tropical Cyclone Formation Alert was issued on the suspect area, and the first JTWC warning was issued at 180900Z September. TD 12W remained south of the mid-tropospheric subtropical ridge throughout its existence and as a result, tracked persistently northwestward. TD 12W made landfall near Cua Ho, Vietnam around 191800Z September and rapidly dissipated over land. After seven warnings, the final warning was issued on 192100Z September.

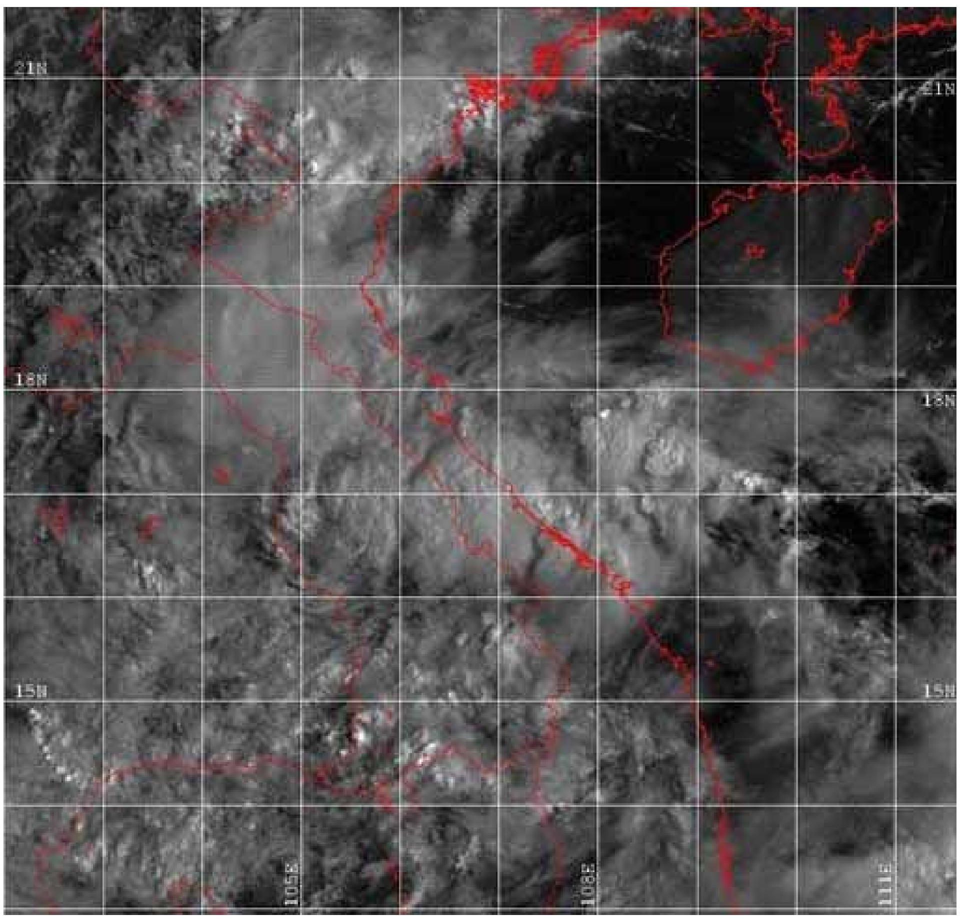
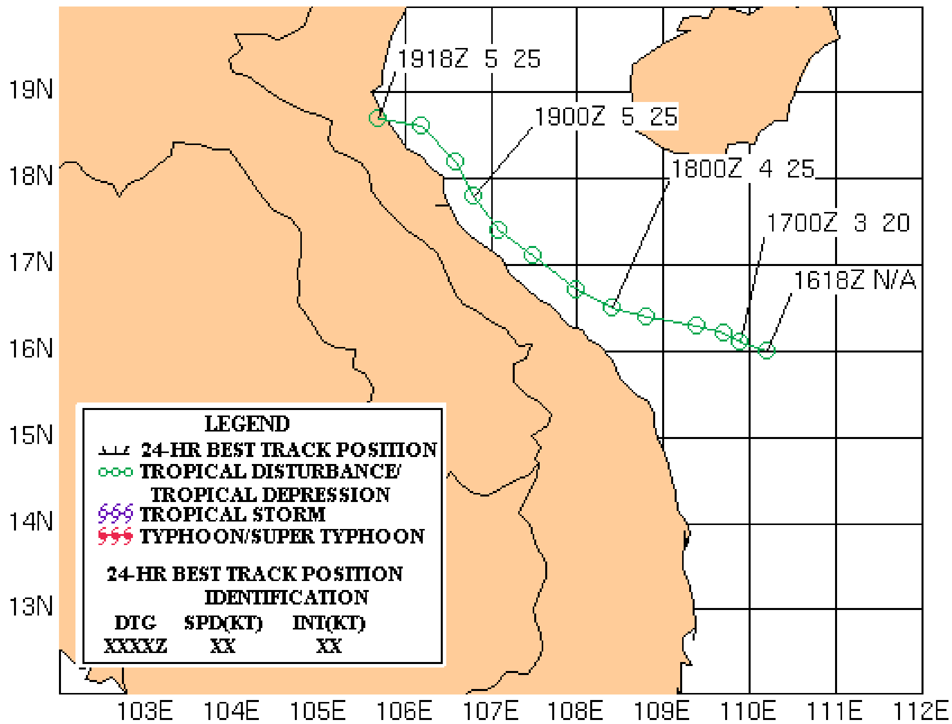


Figure 3-12-1. 190032Z GMS visible imagery indicating a poorly organized TD 12W moving toward the Vietnam coast.


1918Z 5 25
1900Z 5 25
1800Z 4 25
1700Z 3 20
1618Z N/A
19N
18N
17N
16N
15N
14N
13N
103E
104E
105E
106E
107E
108E
109E
110E
111E
112E
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Tropical Storm Waldo (13W)

Tropical Storm Waldo (13W), a small-sized tropical cyclone, developed in the Philippine Sea southwest of Iwo Jima around 20 September. It moved north and dissipated in the Sea of Japan on 21 September. The proximity of TY Vicki (11W), a larger cyclone, affected TS Waldo's movement and intensity.

JTWC issued a Tropical Cyclone Formation Alert at 190900Z September. The first warning was issued at 200300Z September. TS Waldo developed and moved faster than forecast, reaching tropical storm intensity at 200600Z September while moving north at 20 kt. The rapid acceleration northward was due to the proximity of TY Vicki (11W) to the southwest. JTWC forecasts called for TS Waldo to rotate cyclonically around TY Vicki and slowly intensify. Instead, TS Waldo moved northward and accelerated due to an increase in the synoptic scale southerly wind flow between TY Vicki and the mid-tropospheric subtropical ridge located to the northeast of TS Waldo. Additionally, the upper-level outflow from TY Vicki suppressed the outflow from TS Waldo, resulting in a 45 kt maximum intensity.

Landfall occurred near Owase, Japan on Honshu Island around 210800Z September. TS Waldo crossed Japan and dissipated over the Sea of Japan.

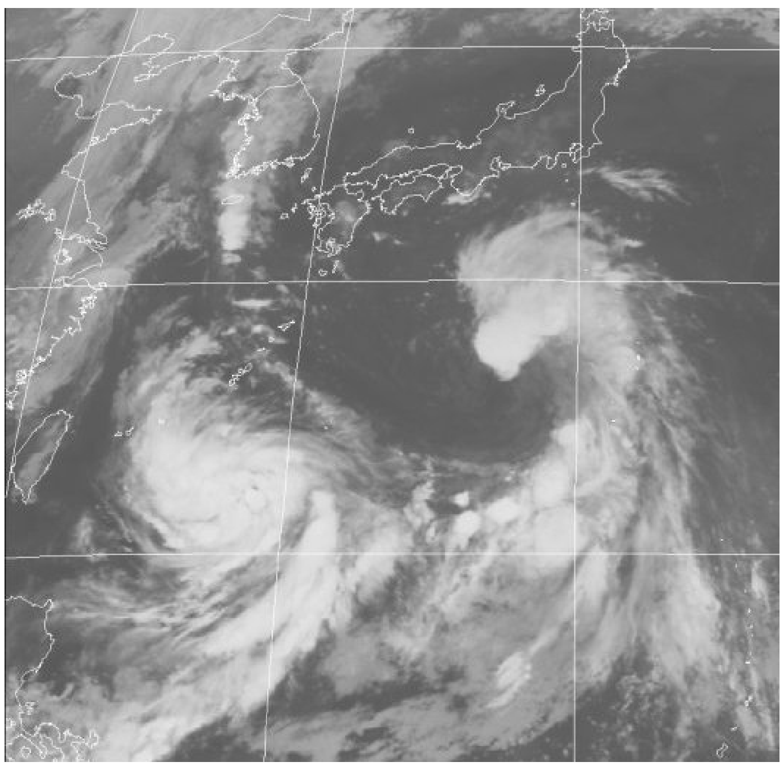
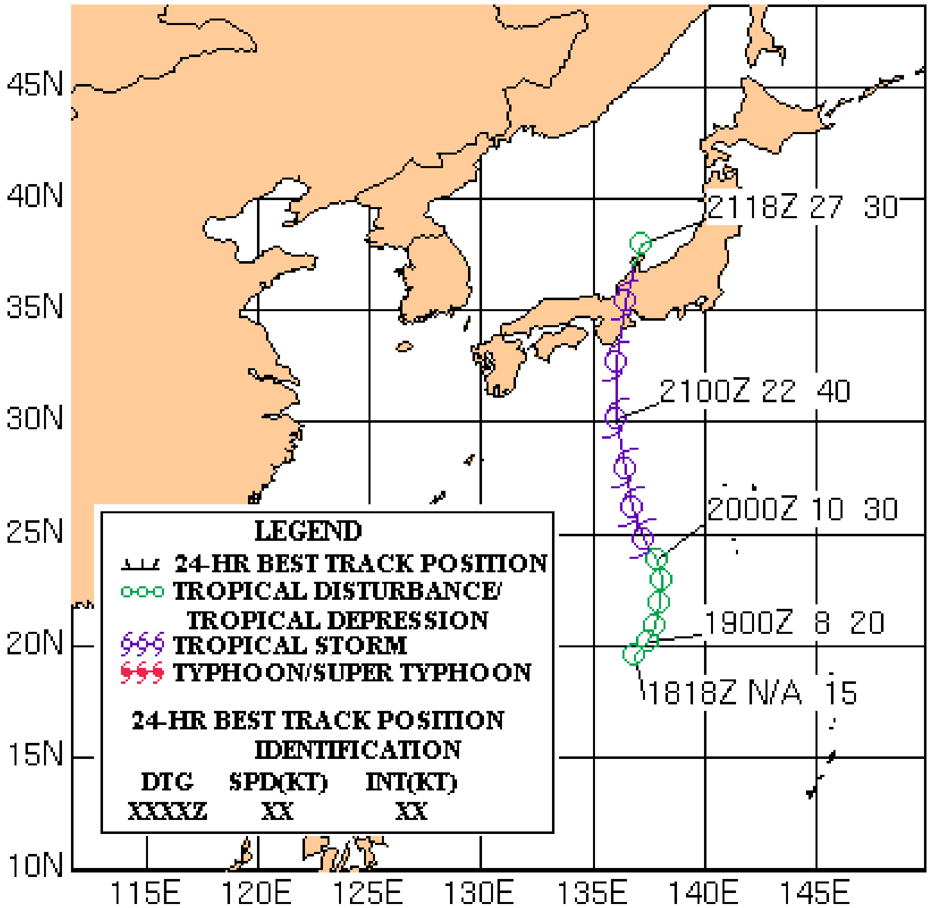


Figure 3-13-1. 201134Z September infrared satellite imagery when TS Waldo was a 35 kt system just south of Japan and TY Vicki (11W) was located southwest of TS Waldo and east of Taiwan.



45N
40N
35N
30N
25N
20N
15N
10N
115E
120E
125E
130E
135E
140E
145E
2118Z 27 30
2100Z 22 40
2000Z 10 30
1900Z 8 20
1818Z N/A 15
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Typhoon Yanni (14W)

Typhoon Yanni (14W) formed in the Philippine Sea and intensified slowly while moving northwestward. As TY Yanni approached Taiwan, this cyclone intensified to typhoon strength and moved northeastward toward Cheju Island, Republic of South Korea. TY Yanni weakened off the coast of Korea then turned south and dissipated near the Ryukyu Islands in the East China Sea.

A Tropical Cyclone Formation Alert was issued for TY Yanni on 242300Z September. JTWC issued the first warning at 250300Z September when TY Yanni was a 25 kt system moving northwestward. TY Yanni maintained a relatively steady track toward Taiwan and reached tropical storm intensity on 271200Z September. TY Yanni then slowed and began to move northward while continuing to intensify. The cyclone reached typhoon intensity on 280600Z while tracking north toward the Korean Peninsula at 8 kt. On 290000Z September, the cyclone accelerated and reached a maximum intensity of 80 kt.

TY Yanni began to weaken as it moved along the eastern periphery of the mid-tropospheric subtropical ridge and encountered more vertical wind shear. As TY Yanni passed over Cheju Island at 300000Z, it weakened to 55 kt. TS Yanni struck South Korea near Yeosu as a 50 kt system on 300700Z September.

After making landfall, Yanni became an exposed low level circulation. It tracked south-southeastward before dissipating near the Ryukyu Islands. The final warning was issued at 010900Z October.

According to a South Korean News Agency, TY Yanni killed 50 people and forced thousands to flee their homes.

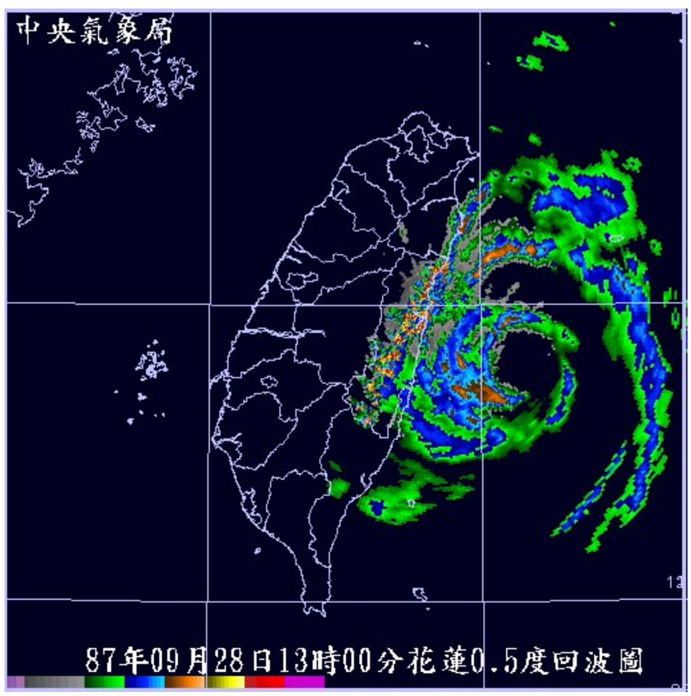


Figure 3-14-1. 2813001Z September Taiwan Doppler Radar depiction of Typhoon Yanni just after reaching typhoon intensity.

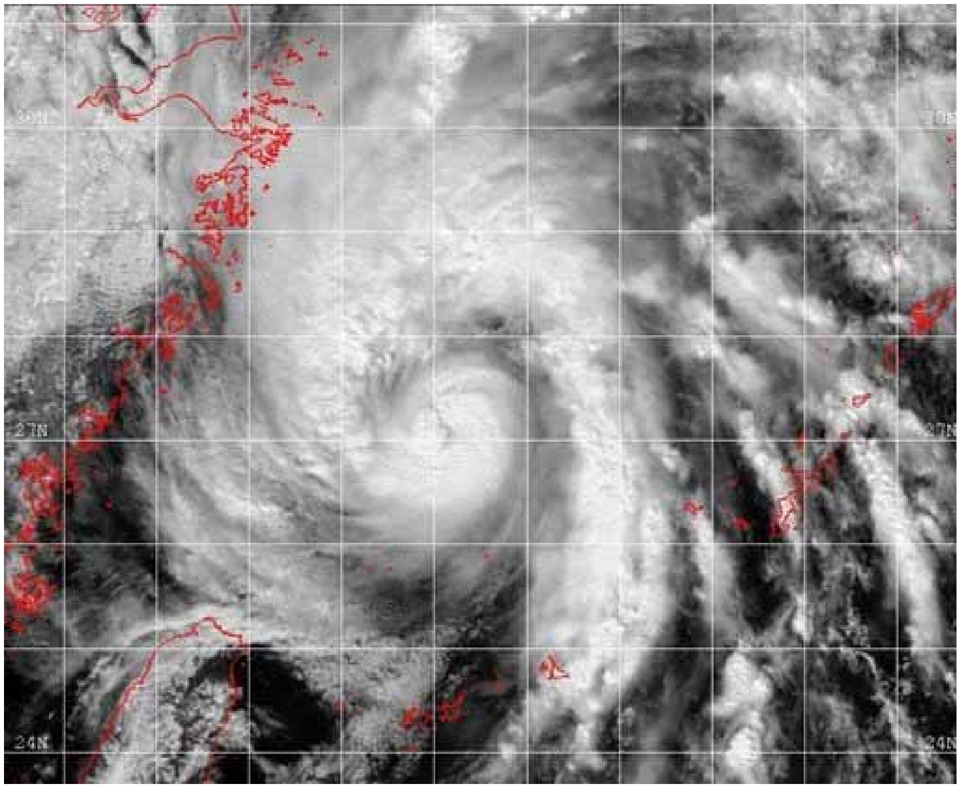
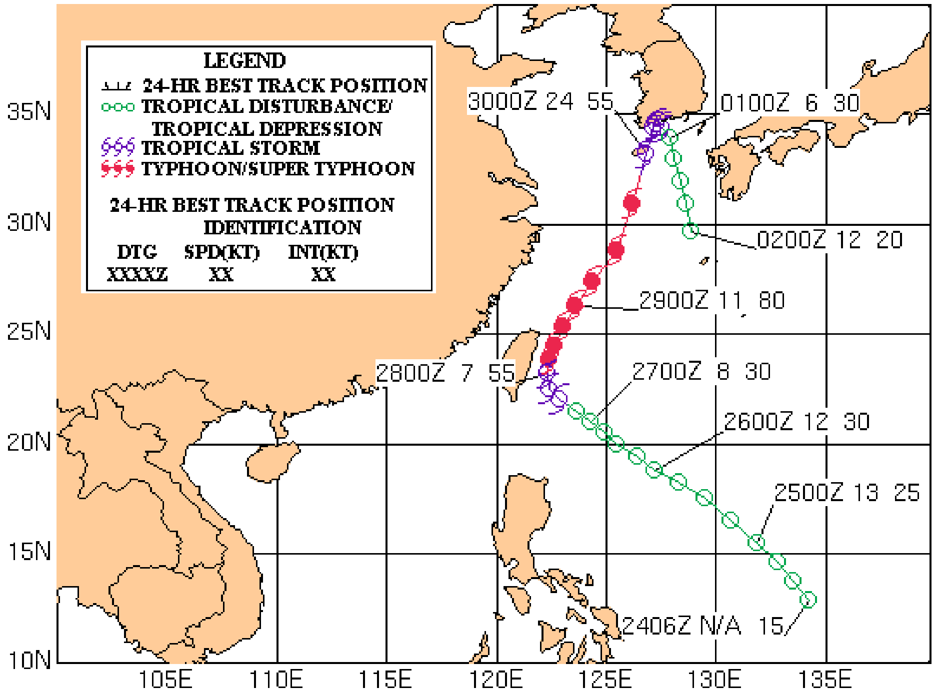


Figure 3-14-2. 280425Z visible satellite image of Typhoon Yanni northeast of Taiwan at it's maximum intensity of 80 kt, courtesy of the Taiwan Weather Agency.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
3000Z 24 55
0100Z 6 30
0200Z 12 20
2900Z 11 80
2800Z 7 55
2700Z 8 30
2600Z 12 30
2500Z 13 25
2406Z N/A 15
35N
30N
25N
20N
15N
10N
105E
110E
115E
120E
125E
130E
135E

Tropical Depression (15W)

Tropical Depression 15W, developed in a broad area of surface troughing in the South China Sea, and meandered northwest before dissipating over northern Vietnam less than 72 hours later.

JTWC issued a Tropical Cyclone Formation Alert at 020700Z October. The first warning was issued 030900Z October as a 30 kt tropical depression. Although initially forecast to reach tropical storm intensity, TD 15W, failed to develop due to vertical windshear. Southeasterly low level synoptic flow steered TD 15W steadily northwestward at 7 to 10 kt toward Vietnam. The cyclone made landfall near Vinh, Vietnam at 051200Z October with a maximum intensity of 30 kt.

Tropical Depression 15W dissipated quickly after moving over land and JTWC issued the final warning at 052100Z October.

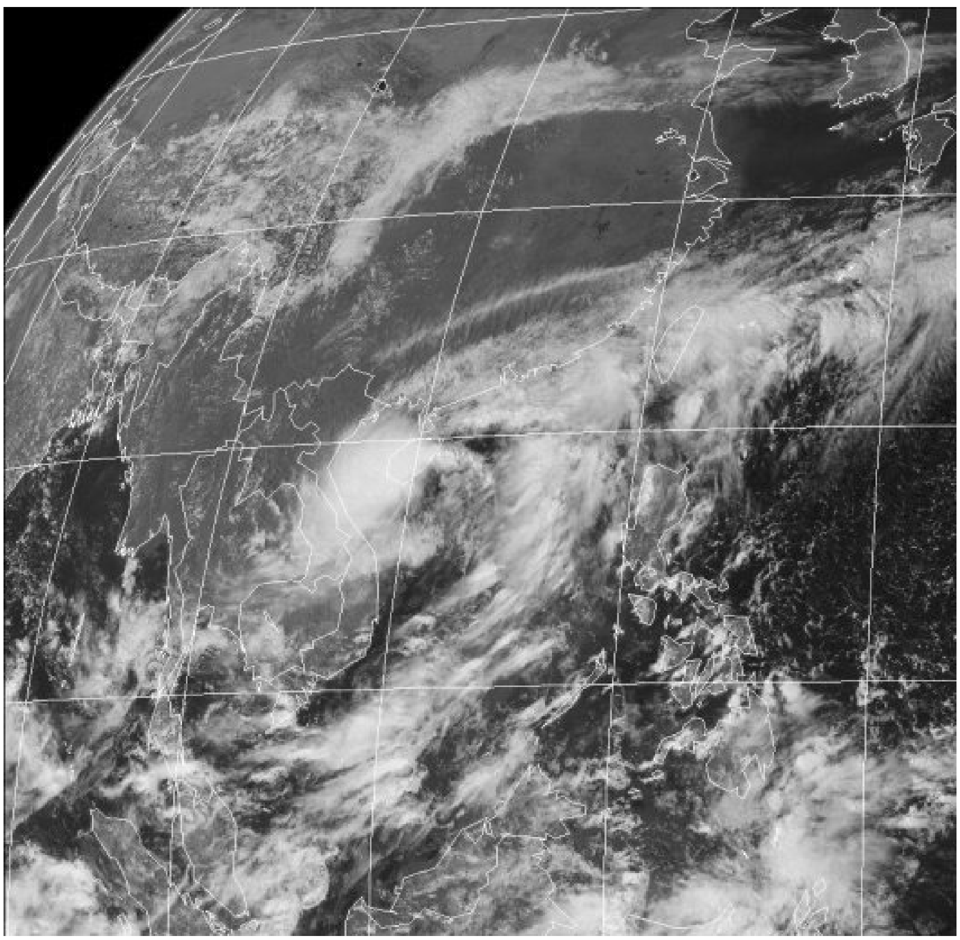
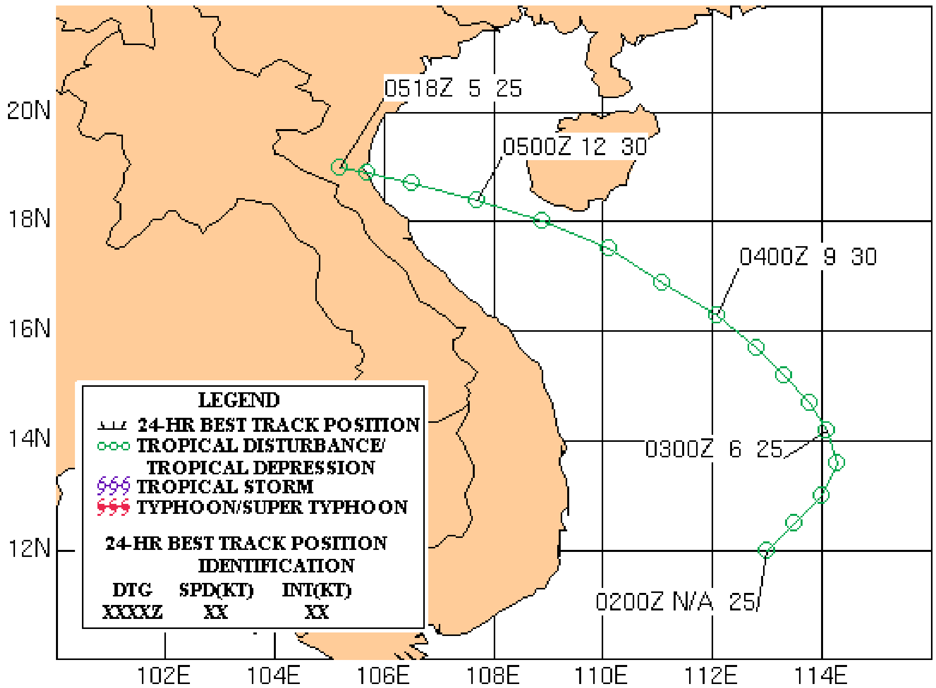


Figure 3-15-1. 040534Z October visible image of TD 15W when the cyclone was located just south of Hainan Island.


20N
18N
16N
14N
12N
102E
104E
106E
108E
110E
112E
114E
0518Z 5 25
0500Z 12 30
0400Z 9 30
0300Z 6 25
0200Z N/A 25
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Tropical Depression 16W

Tropical Depression 16W developed east of Taiwan, moved northeastward and then dissipated south of Okinawa in October.

This cyclone, which developed in a surface trough located over Taiwan and the Ryukyu Islands, was first mentioned in the Significant Tropical Weather Advisory on October 3rd as an area of persistent convection. JTWC issued a Tropical Cyclone Formation Alert at 041630Z October. The initial warning was issued at 050900Z as a 25 kt system located east of Taiwan.

TD 16W remained quasi-stationary in an area of weak steering flow for 36 hours and reached a peak intensity of 30 kt at 061200Z. A passing frontal boundary then moved the system east-northeastward. Vertical shear increased and by 070900Z, TD 16W was an exposed low-level circulation. JTWC issued the final warning at 072100Z October.

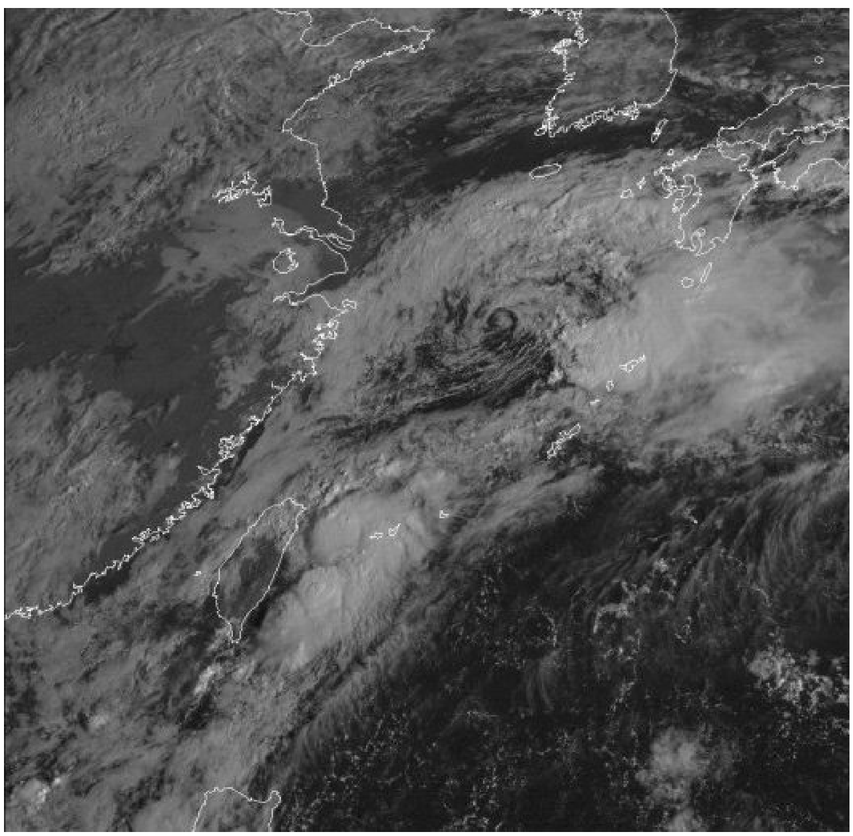
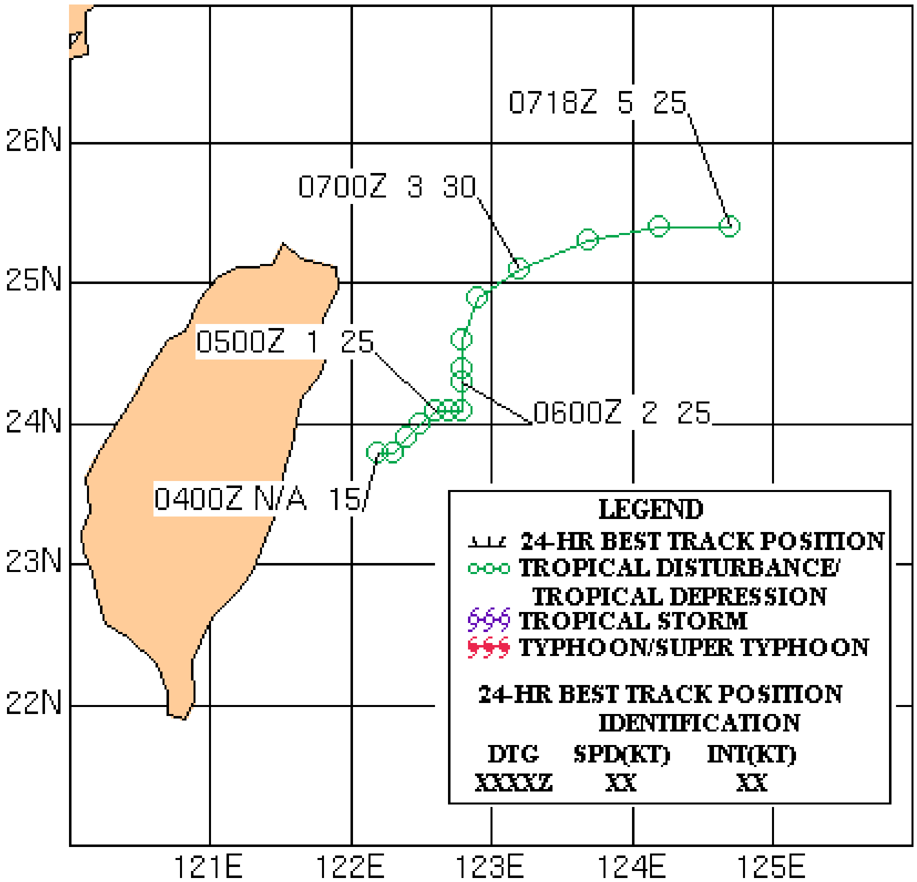


Figure 3-16-1. 052334Z October visual satellite image of TD 16W located east of Taiwan with maximum intensity of 25 kt. Also evident in this data is TD 17W as a completely exposed low level circulation in the East China Sea.


0718Z 5 25
0700Z 3 30
0500Z 1 25
0600Z 2 25
0400Z N/A 15
26N
25N
24N
23N
22N
121E
122E
123E
124E
125E
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Tropical Depression 17W

Tropical Depression 17W was a short-lived cyclone that developed and dissipated as an exposed low level circulation in the East China Sea during early October. Five warnings were issued by JTWC.

TD 17W formed in the reverse orientated monsoon trough and was initially detected by visual satellite data as an exposed low level circulation. The first warning was issued at 060300Z October.

TD 17W was forecast to remain weak as synoptic and satellite data indicated a high vertical wind shear environment. Within 12 hours, TD 17W weakened to a 20 kt system. JTWC issued the final warning at 070300Z October.

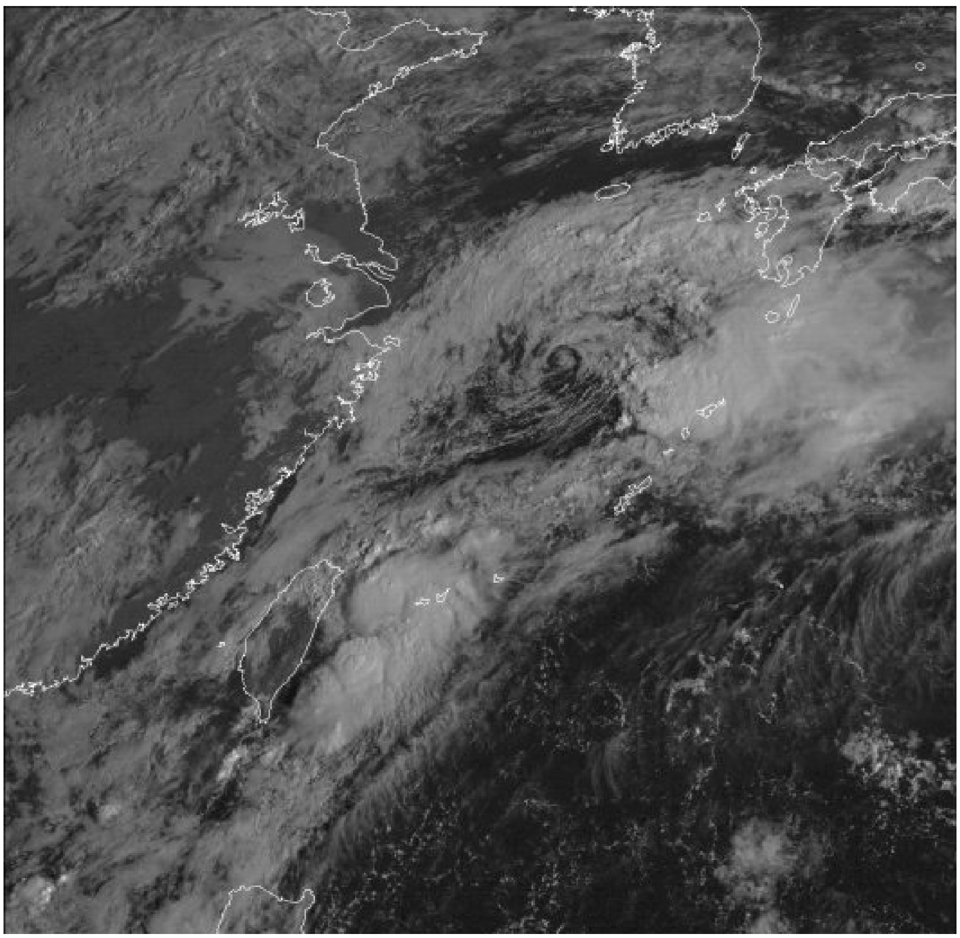
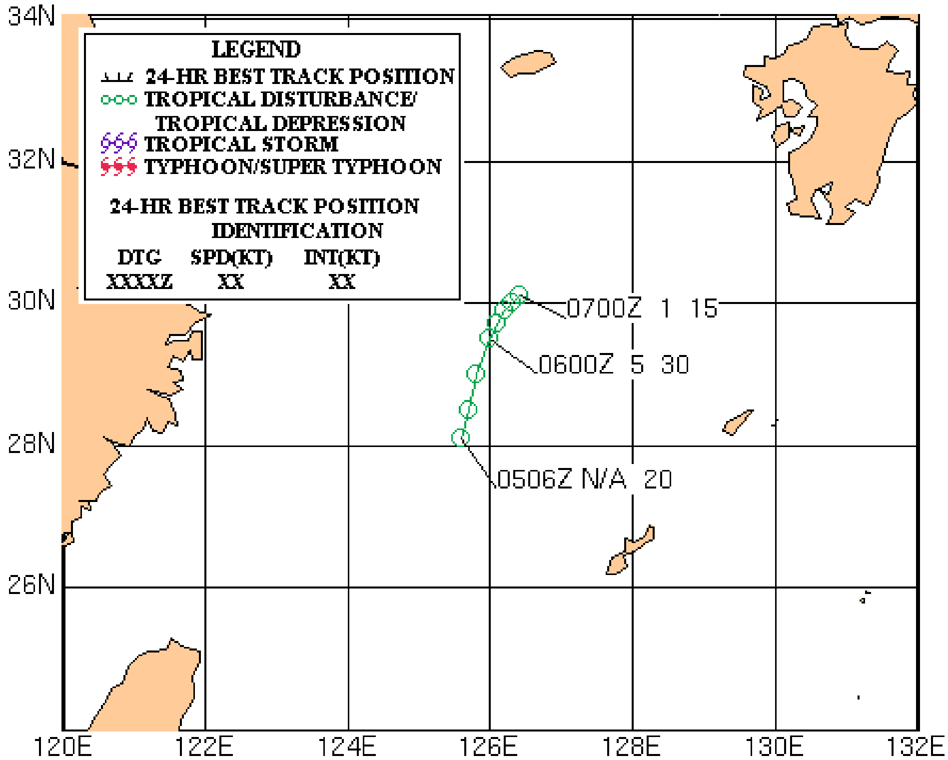


Figure 3-17-1. 052334Z October visible satellite data of TD 17W at maximum intensity of 30 kt with a totally exposed low level circulation.



LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
0700Z 1 15
0600Z 5 30
0506Z N/A 20
34N
32N
30N
28N
26N
120E
122E
124E
126E
128E
130E
132E

Super Typhoon Zeb (18W)

Super Typhoon (STY) Zeb (18W) formed in early October in the monsoon trough southeast of Guam and moved northwest passing over northern Luzon, then north and northeast passing east of Taiwan and over all four of the main Japanese islands. During its transit through the Philippine Sea, this cyclone attained super typhoon intensity of 155 kt just prior to a northern Luzon landfall.

A TCFA was issued on 090630Z October for a tropical disturbance located southeast of Guam. The first warning was issued at 092100Z October when the cyclone was southwest of Guam.

The cyclone intensified to tropical storm strength as it moved north of Yap Island. During intensification, the WSR-88D radar on Guam detected another cyclone embedded in the inflow. This new cyclone was warned on as TS Alex (19W).

TS Zeb (18W) was upgraded to a typhoon at 111800Z October. Zeb attained super typhoon intensity on 130000Z October and reached a peak intensity of 155 kt prior to landfall in the Philippines just south of Palanan Bay, Luzon Island. During passage over northern Luzon, STY Zeb (18W) began to weaken and moved north toward Taiwan. After passing just 10 nm east of Taiwan, the cyclone moved northeast and accelerated. The forward motion of the cyclone reached 48 kt as STY Zeb (18W) underwent extratropical transition over southern Japan and the Sea of Japan. The final warning was issued at 180300Z October.

STY Zeb (18W) was the first of two super typhoons to strike Luzon within 7 days STY Babs (20W) was the second). STY Zeb caused 74 deaths in Luzon and 25 fatalities in Taiwan.

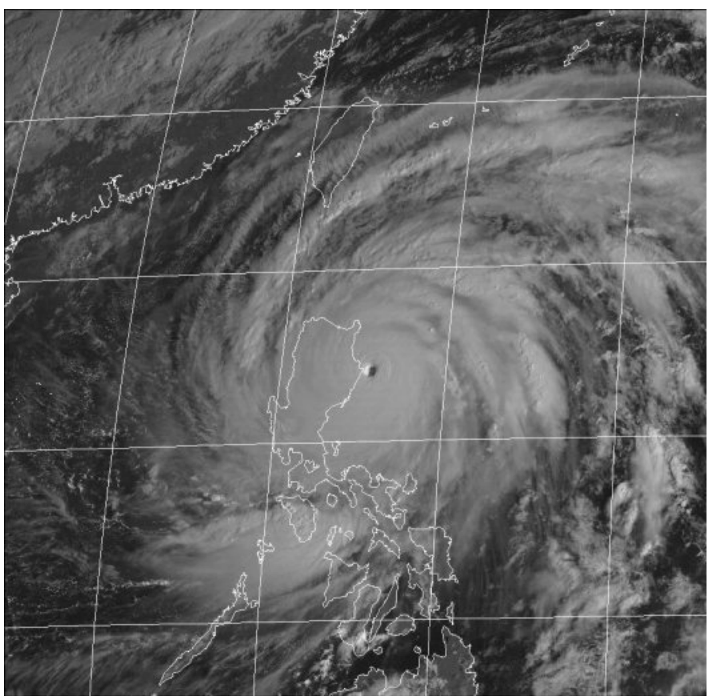
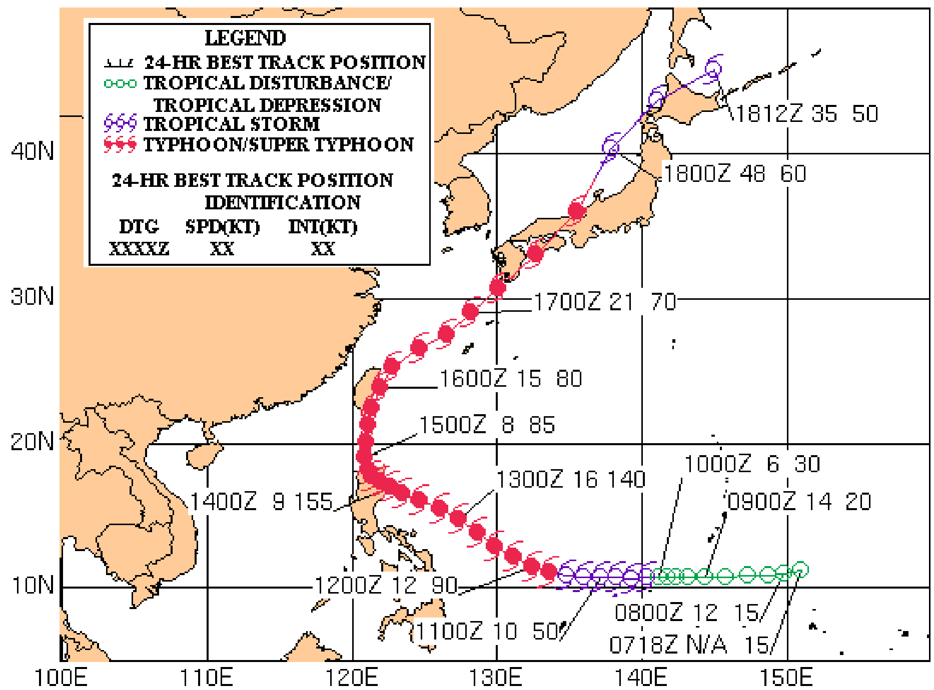


Figure 3-18-1. Super Typhoon Zeb (18W) at 155 kt intensity just before landfall over northern Luzon.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
1812Z 35 50
1800Z 48 60
1700Z 21 70
1600Z 15 80
1500Z 8 85
1400Z 9 155
1300Z 16 140
1200Z 12 90
1100Z 10 50
1000Z 6 30
0900Z 14 20
0800Z 12 15
0718Z N/A 15
40N
30N
20N
10N
100E
110E
120E
130E
140E
150E

Tropical Storm Alex (19W)

TS Alex (19W) was a very small tropical cyclone that formed in the northern inflow of STY Zeb (18W) when STY Zeb was an intensifying tropical storm. TS Alex (19W) existed for only 60 hrs and attained a maximum intensity of 45 kt before the cyclone became sheared in the vertical and the low level circulation was absorbed by STY Zeb (18W).

This cyclone was first detected on the Guam WSR-88D radar imagery while STY Zeb (18W) was passing north of Ulithi Island. The radar data as well as a 40 kt wind report from Rota Island resulted in the first warning, issued at 110300Z October.

TS Alex (19W) maintained westward movement north of Zeb until 120600Z October. TS Alex then turned southwestward and underwent vertical shearing. The remaining low level circulation center was absorbed by STY Zeb (18W). The final warning was issued at 122100Z October.

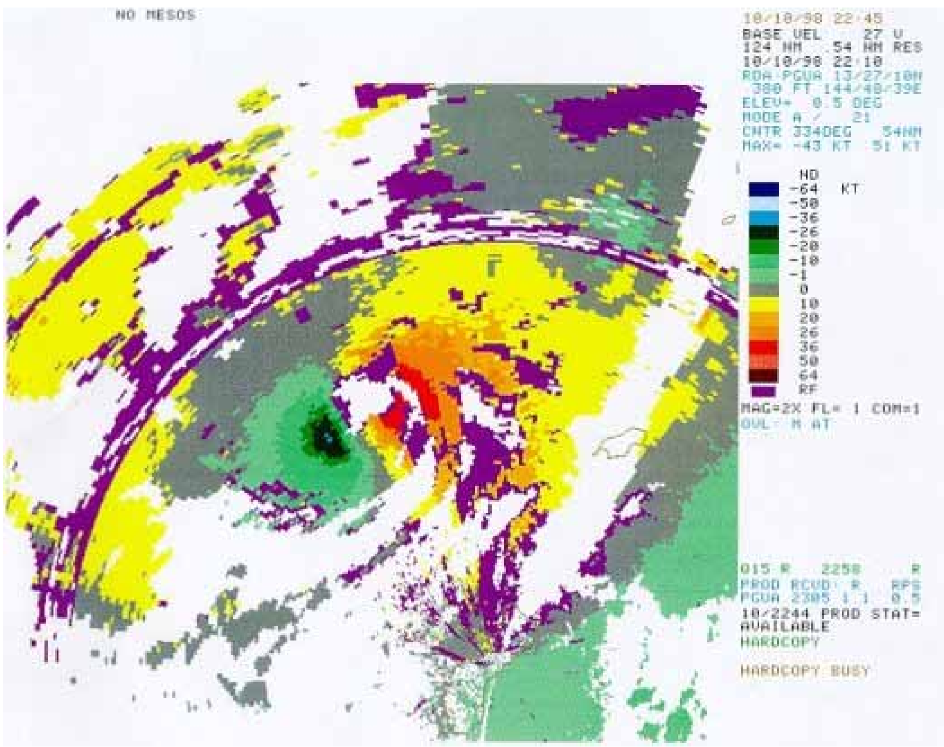
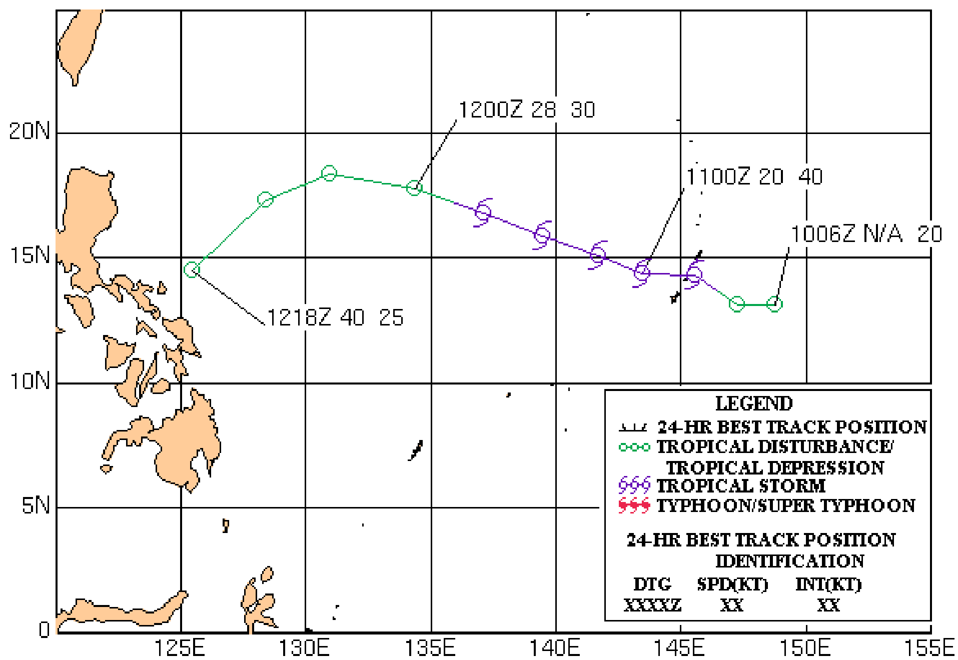


Figure 3-19-1. WSR-88D velocity profile data depicting TS Alex (19W) in a feeder band of STY Zeb (18W).


1200Z 28 30
1100Z 20 40
1006Z N/A 20
1218Z 40 25
20N
15N
10N
5N
0
125E
130E
135E
140E
145E
150E
155E
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Super Typhoon Babs (20W)

Super Typhoon Babs (20W), the second super typhoon within a 7-day period to strike the Philippines, was initially detected as a tropical disturbance southeast of Guam. While moving west and intensifying, interaction with a Tropical Upper Tropospheric Trough (TUTT) caused the cyclone to slow and move southward for a 36-hour period in the Philippine Sea. As the TUTT filled, TY Babs reached super typhoon intensity (maximum intensity of 135 kt) while moving northwestward off the coast of Mindanao. Passage over central Luzon caused Super Typhoon (STY) Babs to weaken, while steering currents caused a track change northward. A subsequent increase in vertical shear and proximity to land led to rapid weakening and dissipation in the Taiwan Strait.

The initial TCFA was issued at 120900Z October. The first warning was issued at 140900Z October. The system was upgraded to a tropical storm at 150600Z October as it moved westward toward the Philippines at 10 kt.

At approximately 171200Z, TY Babs began to weaken and move south in response to the influence of the TUTT located to the northeast. The TUTT weakened the sub-tropical ridge (thus the slowing and move south) and restricted the cyclone's upper level outflow (the short period of weakening). After the TUTT filled, TY Babs began to re-intensify and moved toward the Philippines, reaching super typhoon intensity on 201200Z October.

STY Babs continued to move northwestward across Cantanduanes and Polillo Islands before making landfall over central Luzon. During passage over Luzon, the cyclone weakened to 85 kt and tracked across the South China Sea where a mid-latitude trough further weakened it and steered it northward.

Super Typhoon Babs (20W) dissipated in the Taiwan Strait due to strong vertical wind shear and the frictional effects of land. The final warning was issued at 272100Z October.

News agencies reported Super Typhoon Babs had a significant impact throughout the Far East. In the Philippines, disastrous mudslides killed 156 people and displaced nearly 400,000 from their homes. In Taiwan, over 20 inches of rain fell in 24 hours, inundating many eastern towns and villages with waist-high flooding. Landslides also wreaked havoc in Taiwan, trapping hundreds in the mountainous interior. In Hong Kong, 64 mph winds closed beaches and kept the local fishing fleet in port.

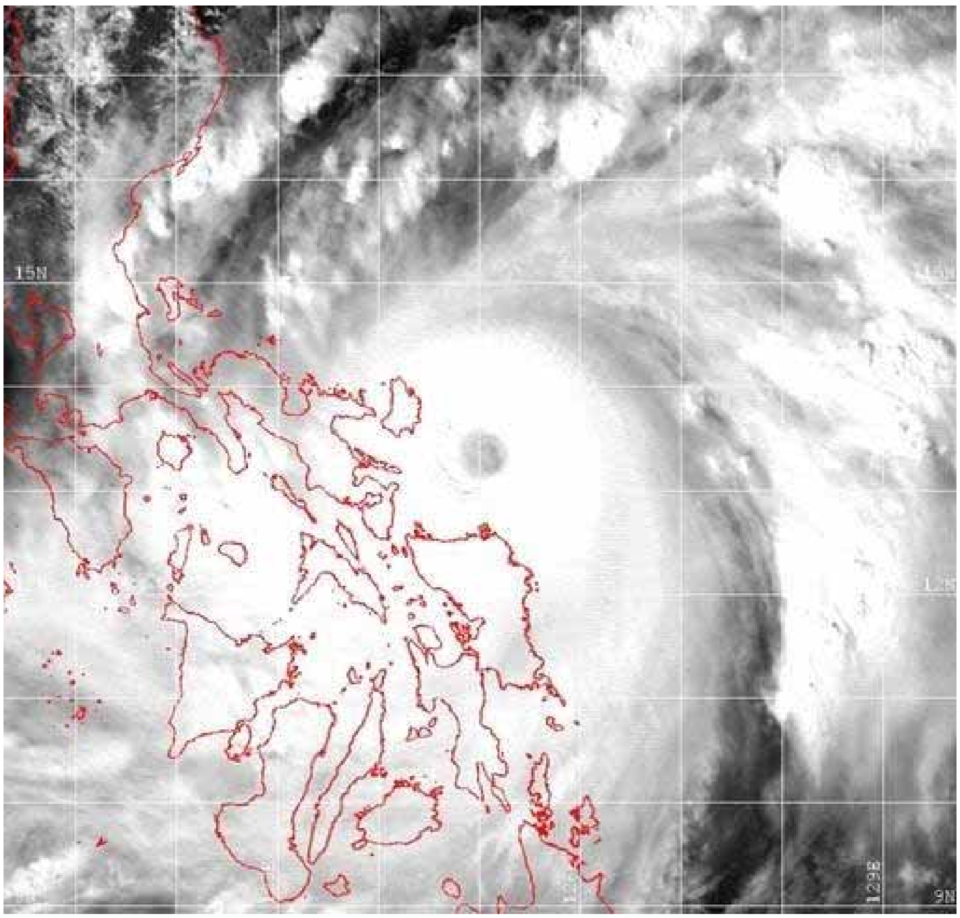
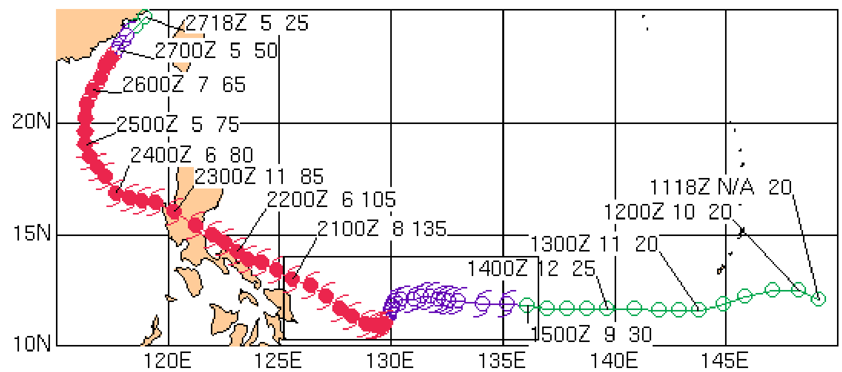
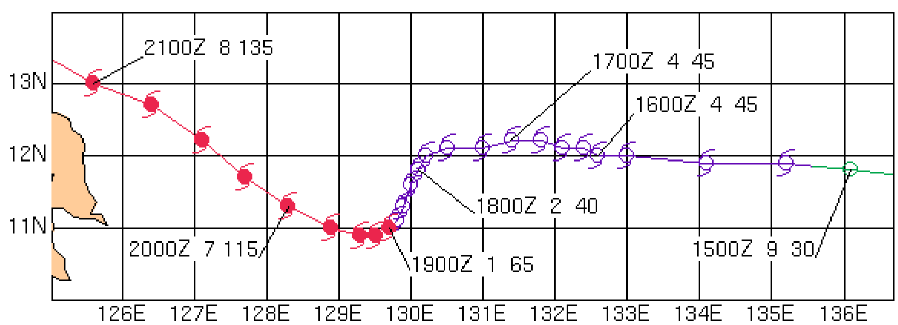
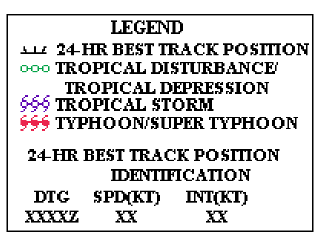


Figure 3-20-1. Visual imagery of Super Typhoon Babs (20W) as it passed over Cantanduanes Island, Philippines.


2718Z 5 25
2700Z 5 50
2600Z 7 65
2500Z 5 75
2400Z 6 80
2300Z 11 85
2200Z 6 105
2100Z 8 135
1400Z 12 25
1300Z 11 20
1200Z 10 20
1118Z N/A 20
1500Z 9 30
20N
15N
10N
120E
125E
130E
135E
140E
145E


2100Z 8 135
1700Z 4 45
1600Z 4 45
1800Z 2 40
2000Z 7 115
1900Z 1 65
1500Z 9 30
13N
12N
11N
126E
127E
128E
129E
130E
131E
132E
133E
134E
135E
136E

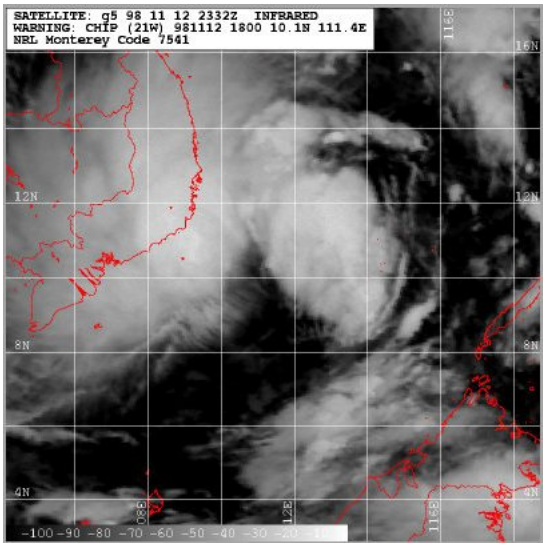

LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

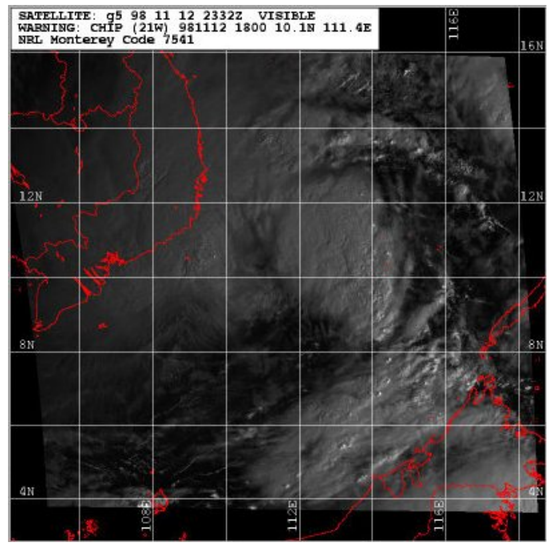
Tropical Storm Chip (21W)

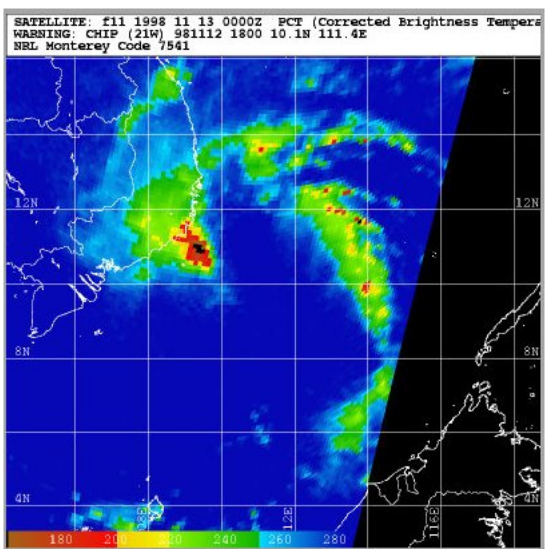
Tropical Storm Chip (21W) developed in mid-November as a shearline-enhanced circulation in the South China Sea, and existed for just over 72 hours before dissipating south of Vietnam.

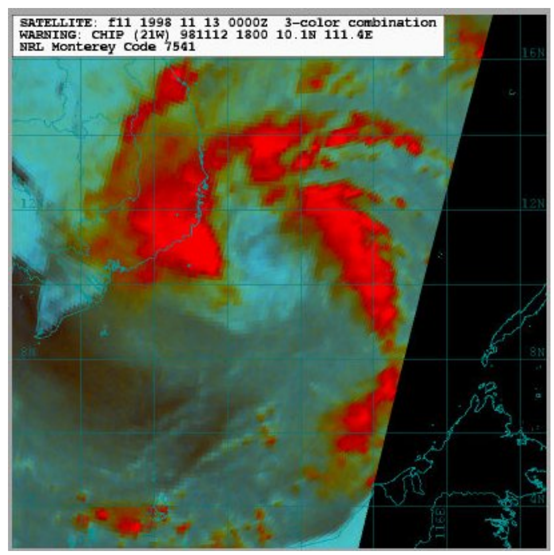
A TCFA was issued at 111230Z November when a broad cyclonic circulation became more organized as a shearline moved into the northern South China Sea. At 120300Z November, the first warning was issued when satellite and synoptic data indicated continued organization.

TD 21W tracked slowly northwestward toward Vietnam, and reached tropical storm intensity at 120600Z November. TS Chip reached a maximum intensity of 50 kt at 131200Z November. As TS Chip moved closer to southern Vietnam the effects of the land interaction and vertical wind shear began to weaken it. TS Chip then turned south and moved along the coast of southern Vietnam, as it continued to weaken. The final warning was issued at 150300Z.


SATELLITE: g5 98 11 12 2332Z INFRARED
WARNING: CHIP (21W) 981112 1800 10.1N 111.4E
NRL Monterey Code 7541
16N
12N
8N
4N
108E
112E
116E
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10


SATELLITE: g5 98 11 12 2332Z VISIBLE
WARNING: CHIP (21W) 981112 1800 10.1N 111.4E
NRL Monterey Code 7541
16N
12N
8N
4N
108E
112E
116E


SATELLITE: f11 1998 11 13 0000Z PCT (Corrected Brightness Tempera
WARNING: CHIP (21W) 981112 1800 10.1N 111.4E
NRL Monterey Code 7541
12N
8N
4N
108E
112E
116E
180 200 220 240 260 280


SATELLITE: f11 1998 11 13 0000Z 3-color combination
WARNING: CHIP (21W) 981112 1800 10.1N 111.4E
NRL Monterey Code 7541
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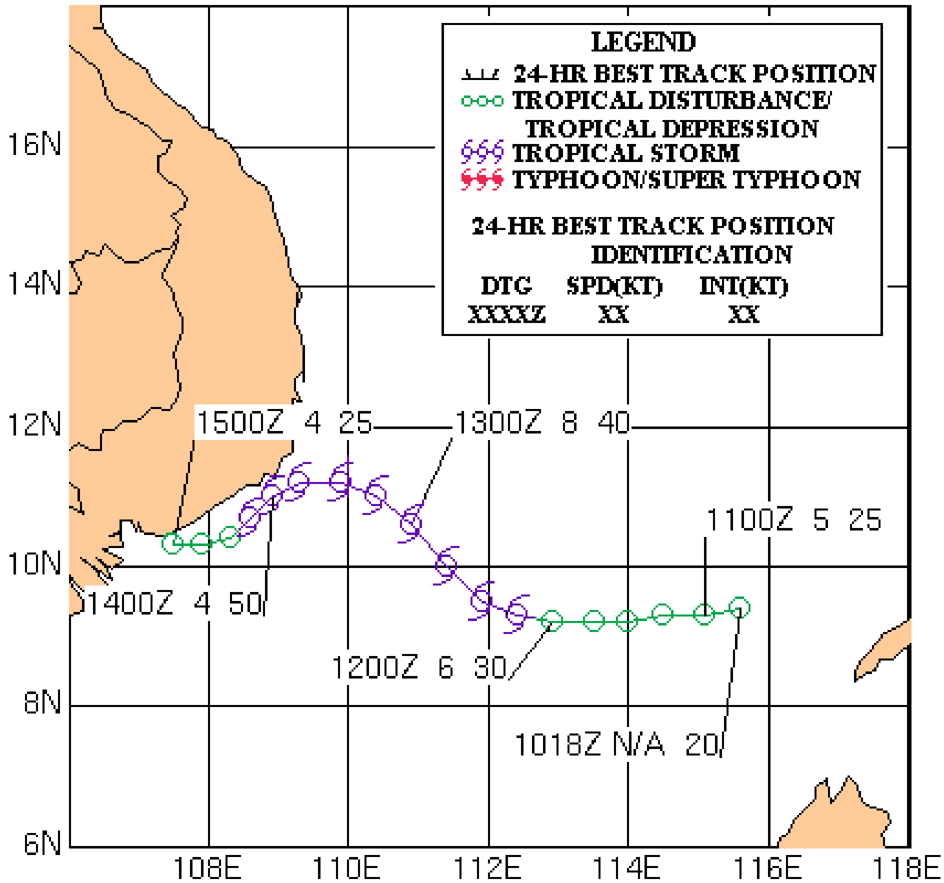
12N
8N
4N
116E


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG
SPD(KT)
INT(KT)
XXXXZ
XX
XX
16N
14N
12N
10N
8N
6N
108E
110E
112E
114E
116E
118E
1500Z 4 25
1300Z 8 40
1100Z 5 25
1400Z 4 50
1200Z 6 30
1018Z N/A 20

Tropical Storm Dawn (22W)

TS Dawn (22W) formed in the South China Sea, moved west, then northwest under the steering influence of the subtropical ridge. Three days later, TS Dawn (22W) dissipated over northern Cambodia.

Initially detected as a tropical disturbance on the 17th, a TCFA was issued at 180030Z November. The first warning on TS Dawn was issued at 180900Z after meteorological satellite data indicated an intensity of 25 kt.

TS Dawn moved northwest, away from an area of strong vertical wind shear and reached tropical storm intensity at 181800Z November. TS Dawn continued to move northwestward, and reached a maximum intensity of 45 kt before making landfall near Cam Ranh, Vietnam at 191500Z November. TS Dawn dissipated over northern Cambodia on 20 November.

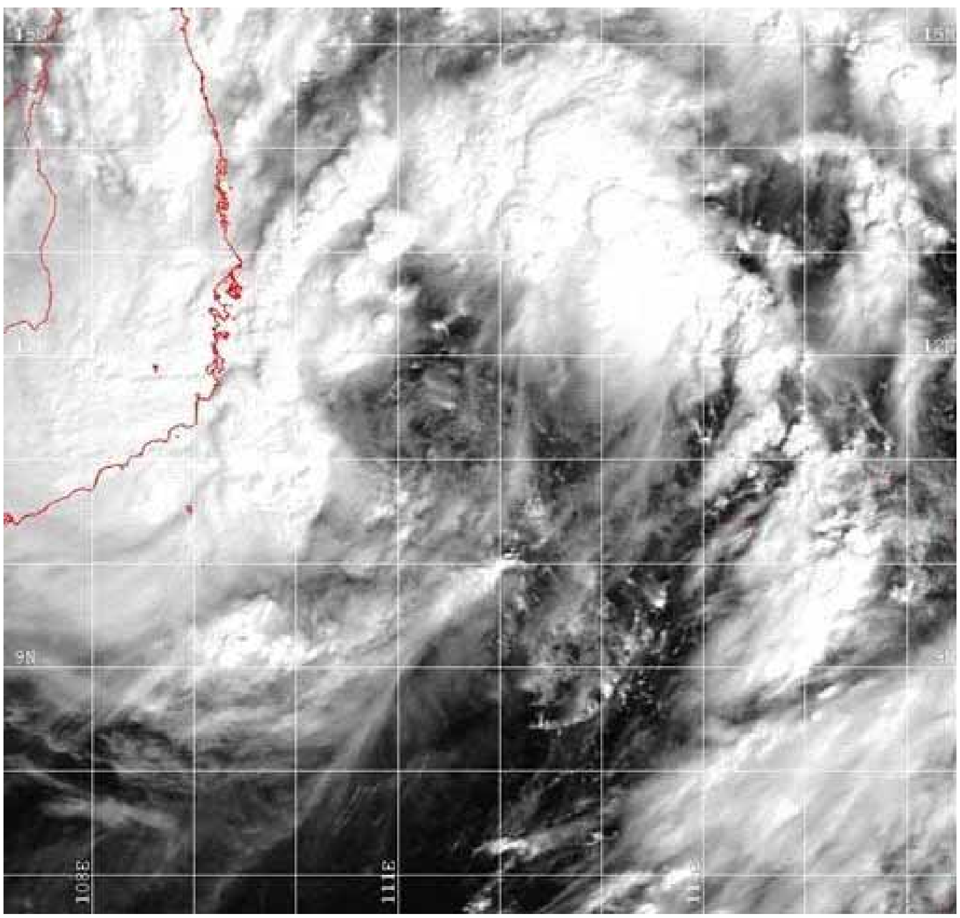
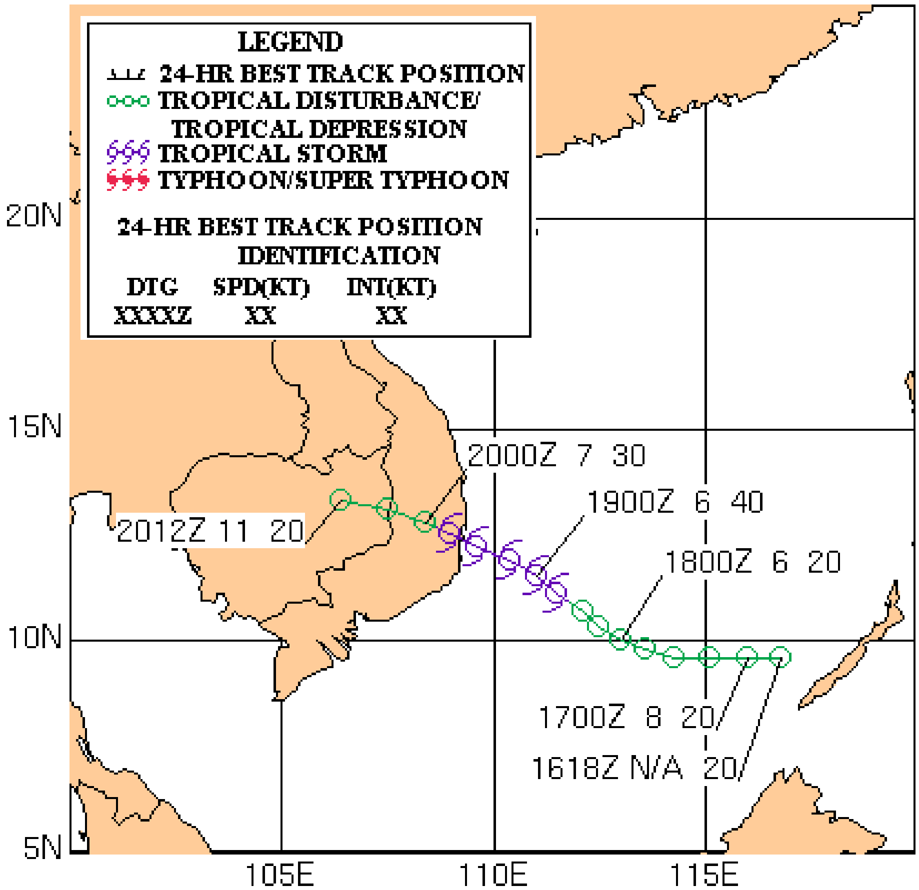


Figure 3-22-1. Visual image of TS Dawn (22W) before landfall with estimated winds of 40 kt. The cyclone would intensify to 45 kt before making landfall in central Vietnam.



LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
20N
15N
10N
5N
105E
110E
115E
2000Z 7 30
1900Z 6 40
2012Z 11 20
1800Z 6 20
1700Z 8 20
1618Z N/A 20

Tropical Storm Elvis (23W)

TS Elvis (23W) was one of 10 tropical cyclones to form in the South China Sea during 1998, roughly twice the number expected (based on JTWC 15 year statistics). A straight-running cyclone, TS Elvis (23W), made landfall in Vietnam causing 49 deaths and flooding damage.

A TCFA was initially issued at 232300Z November for a poorly defined tropical cyclone with the strongest winds on the periphery. The first warning was issued at 240300Z November as ship reports and intensity estimates from satellite data indicated a 25 kt tropical cyclone. The cyclone began tracking west-northwest at 8 kt and reached tropical storm intensity at 241200Z November.

The system continued to move west-northwestward and attained a maximum intensity of 45 kt at 250000Z November. Moderate vertical wind shear prevented further intensification of TS Elvis (23W), which remained at 45 kt until making landfall at 252300Z November. The cyclone moved onshore north of Quy Nhon, Vietnam and dissipated after 12 hours. The final JTWC warning was issued at 260900Z November.

According to reports compiled by the Dartmouth Flood Observatory, Dartmouth College, Hanover, NH, approximately 49 fatalities and 30 million U. S. dollars worth of damage in the Binh Dinh and Quang Ngai provinces of Vietnam resulted from the passage of TS Elvis (23W) and its associated rainfall and flooding.

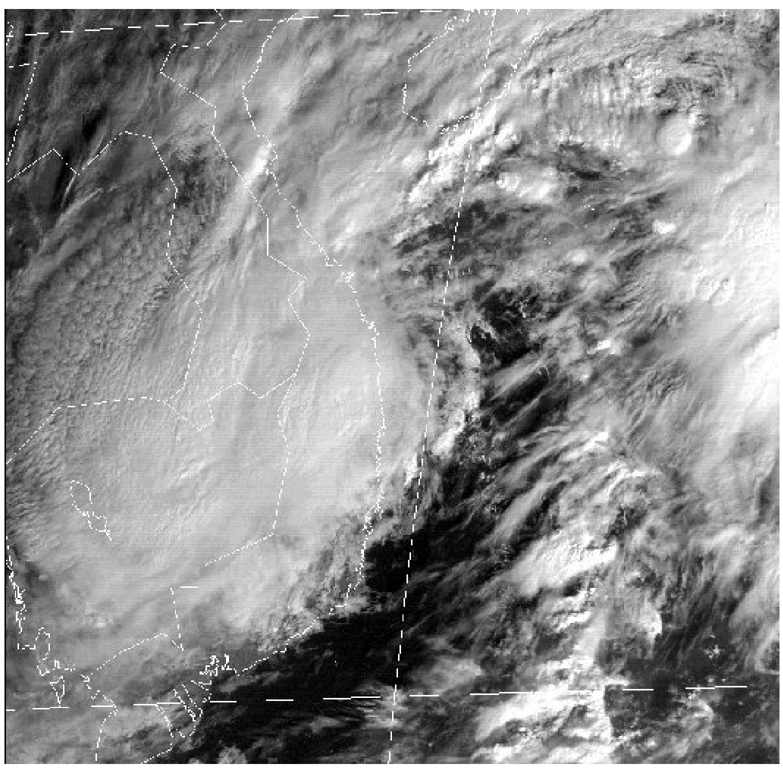
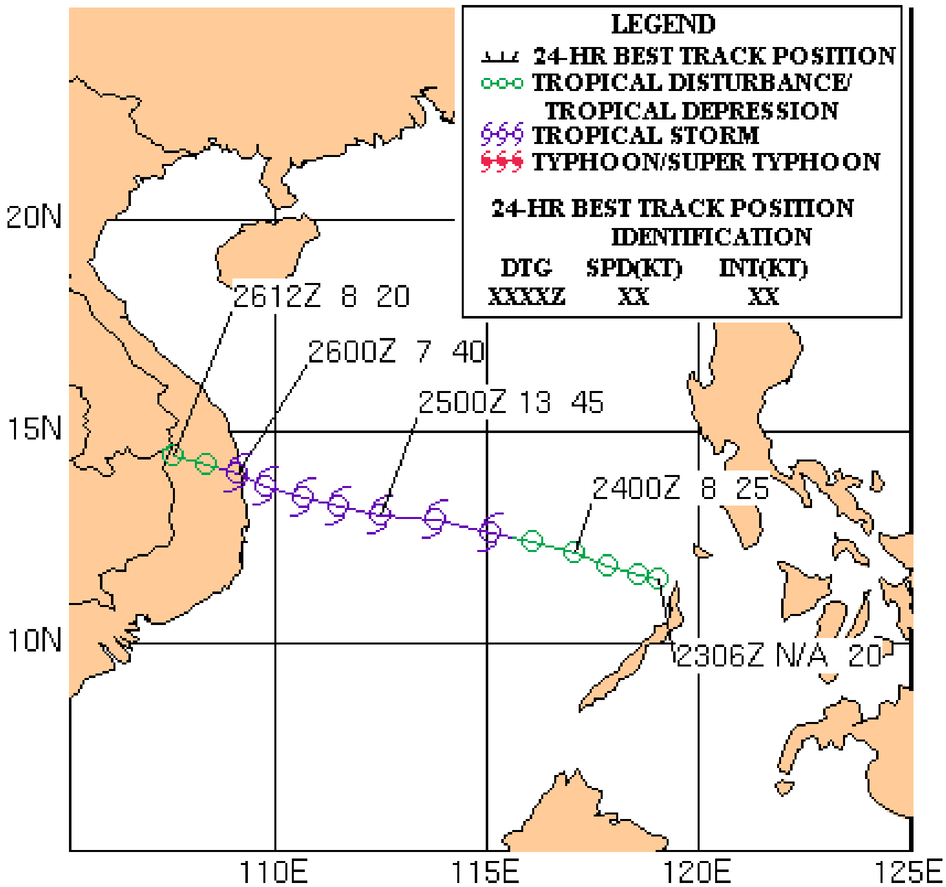


Figure 3-23-1. Visible satellite imagery of TS Elvis just after passing over the Vietnam coast.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
20N
15N
10N
110E
115E
120E
125E
2612Z 8 20
2600Z 7 40
2500Z 13 45
2400Z 8 25
2306Z N/A 20

Typhoon Faith (24W)

Typhoon Faith (24W) formed in the western Caroline Islands, developed into a significant tropical cyclone in the Philippine Sea, and reached typhoon intensity over Samar Island, Philippines. TY Faith (24W) continued to track westward and attained a maximum intensity of 90 kt in the South China Sea. As it continued west, it weakened and made landfall over central Vietnam as a tropical storm.

A Tropical Cyclone Formation Alert was first issued at 080330Z December, when the disturbance was located south of Sorol Atoll, Federated States of Micronesia. The first warning was issued at 080900Z December as conventional infrared, visual, and microwave satellite data and synoptic reports indicated a 25 kt intensity. The first warning forecast rapid (12-18 kt) west-northwest movement and slow intensification.

At 090000Z, TD 24W headed northwestward in response to a weak mid-latitude trough that passed north of the cyclone in the mid-tropospheric westerlies. TD 24W then resumed a westward track toward the central Philippines and was upgraded to TS Faith (24W) at 091800Z December.

Six hours prior to the landfall over Samar Island, the cyclone took another short jog to the northwest in response to a second weak passing mid latitude trough, but again resumed a more westward heading after the trough had passed to the northeast.

TS Faith attained typhoon intensity at 101200Z December while passing over the Philippine island of Samar. TY Faith continued across the central Philippine Islands while maintaining minimal typhoon intensity.

Over the South China Sea, TY Faith intensified while moving west-southwestward at 14 to 18 kt. The cyclone attained a maximum intensity of 90 kt at 111200Z December and maintained this intensity while slowing during the next 24 hours. TY Faith (24W) made a second landfall over Vietnam at 140000Z December near Cam Ranh, Vietnam. The cyclone quickly weakened as it moved inland into central Vietnam and the final warning was issued at 141500Z December.

At least 38 people were reported killed in Vietnam with over 10,000 evacuated due to flooding in low-lying areas. Damage assessments for Vietnam reached over $20 million.

Reports from the Philippines indicated 29 people were killed and over 20,000 were displaced due to the passage of TY Faith. The Philippine Navy rescued 100 people from a disabled ferry travelling from the Philippines to Malaysia. The damage estimate for the Philippines was over $13 million.

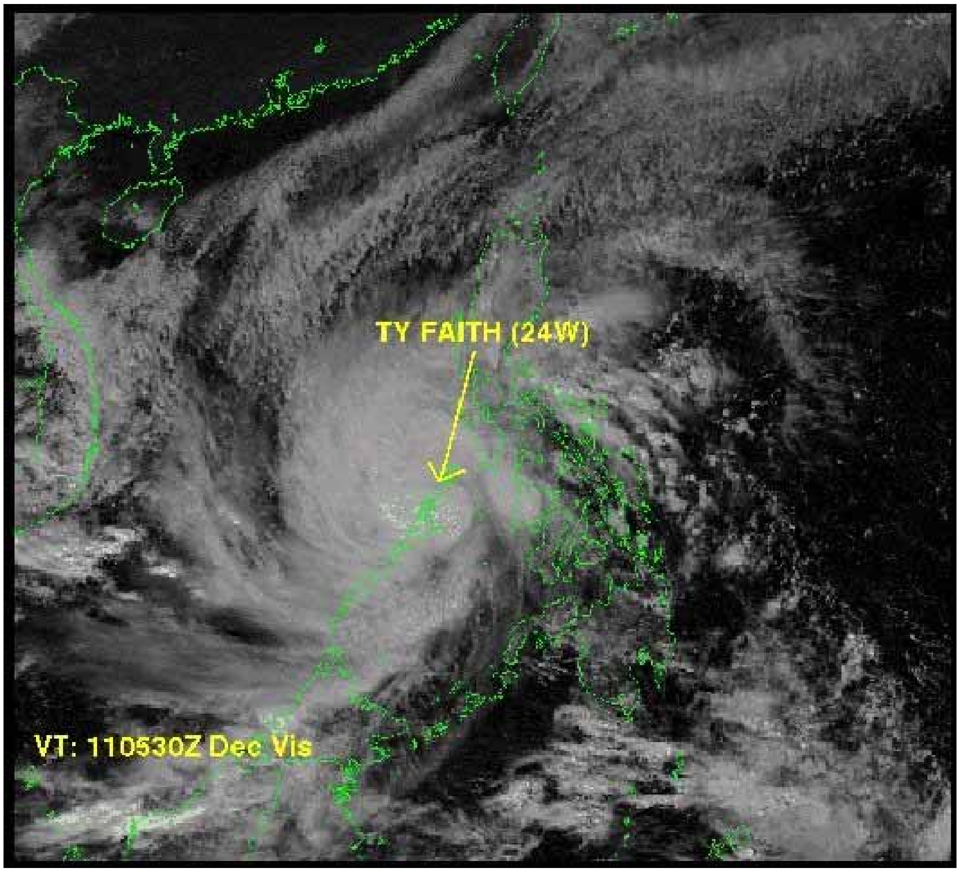
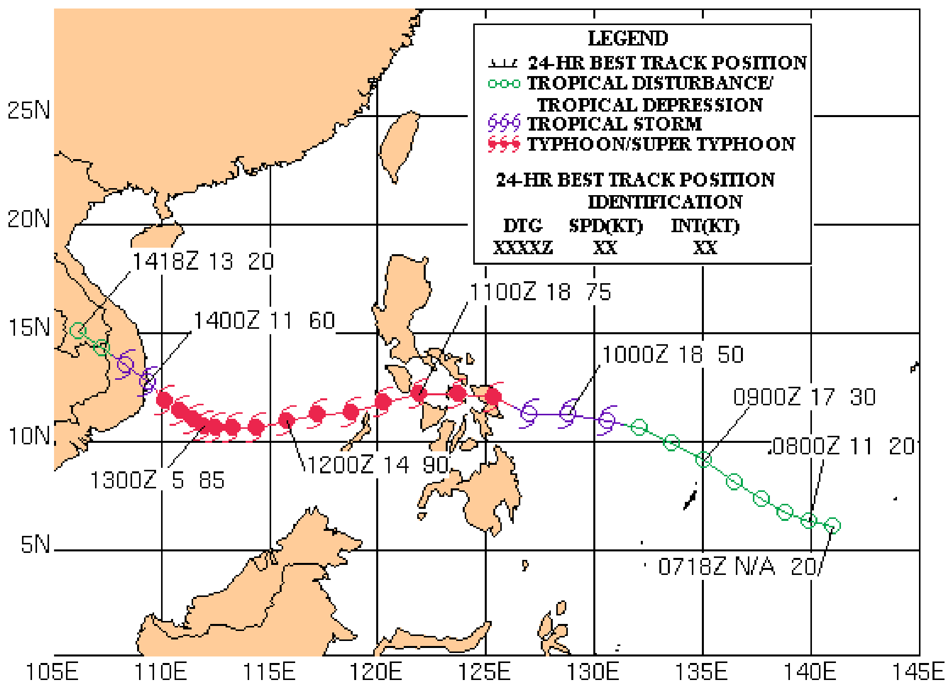


Figure 3-24-1. GMS-5 visible image of TY Faith as it moves into the South China Sea. TY Faith's intensity was 80 kt and it peaked at 90 kt six hours later.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG
SPD(KT)
INT(KT)
XXXXZ
XX
XX
1418Z 13 20
1400Z 11 60
1100Z 18 75
1000Z 18 50
0900Z 17 30
0800Z 11 20
1300Z 5 85
1200Z 14 90
0718Z N/A 20
25N
20N
15N
10N
5N
105E
110E
115E
120E
125E
130E
135E
140E
145E

Tropical Storm Gil (25W):

Tropical Storm (TS) Gil (25W), began as a monsoon depression in the South China Sea, developed off the coast of north Borneo, slowly intensified and attained maximum winds of 35 kt while moving due west. It later dissipated over the Malay Peninsula.

A TCFA was issued at 090530Z December for an area of heavy convection and thunderstorm activity with numerous small cyclonic circulations. The first warning was issued at 091500Z December as satellite and synoptic data indicated consolidation and organization into a single cyclone.

TS Gil (25W) began moving west-northwest at 7 to 9 kt while slowly consolidating and intensifying. It reached tropical storm intensity on 101800Z December. Persistent vertical wind shear caused by mid to upper tropospheric southwesterlies and low to mid tropospheric easterlies and interaction with land inhibited further development.

TS Gil (25W) weakened to 30 kt at landfall over the Malay Peninsula near Songkhla, Thailand and rapidly dissipated. JTWC issued the final warning at 130300Z.

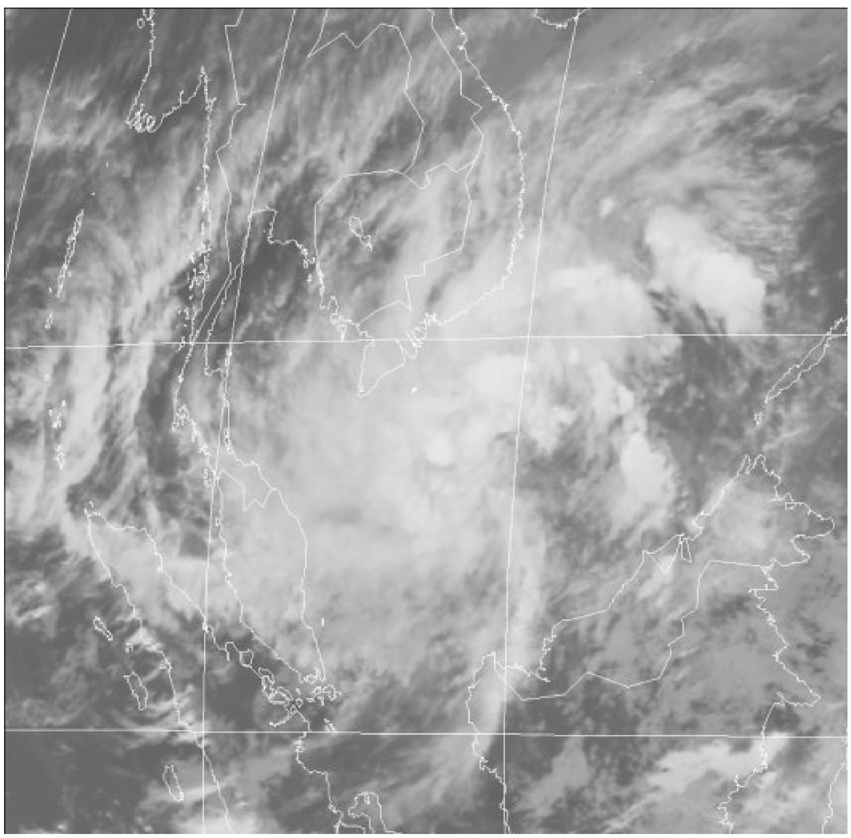
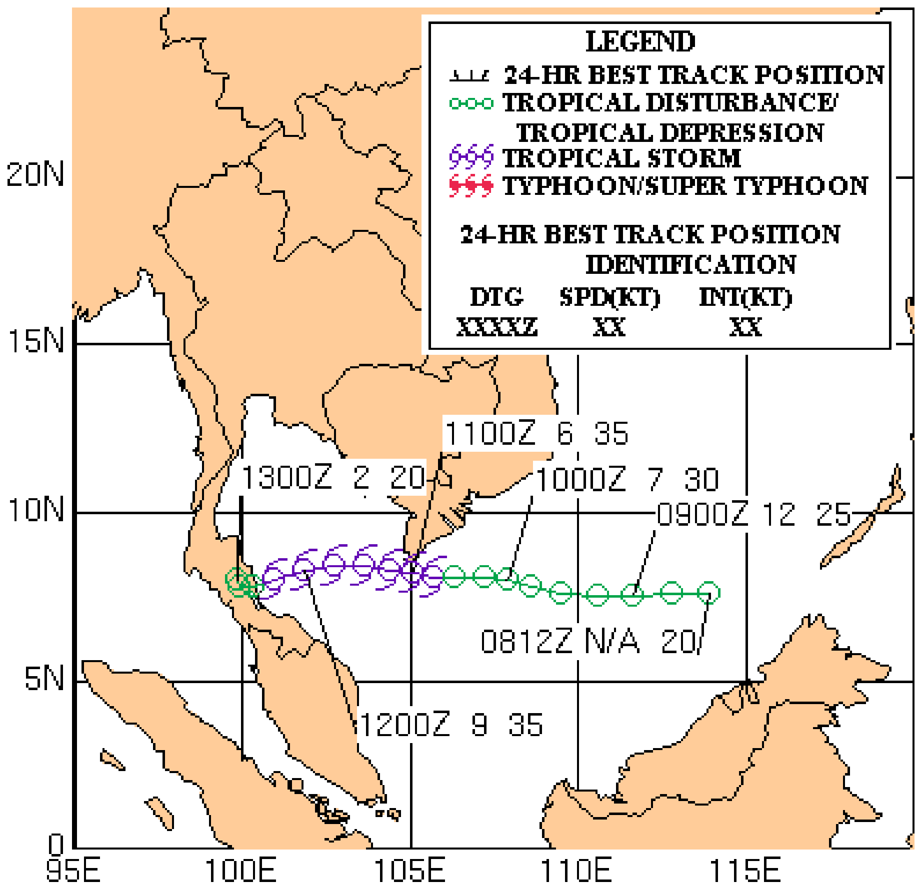


Figure 3-25-1. 091132Z December visible satellite image of TS Gil (25W) at initial warning time.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
1100Z 6 35
1300Z 2 20
1000Z 7 30
0900Z 12 25
0812Z N/A 20
1200Z 9 35
20N
15N
10N
5N
0
95E
100E
105E
110E
115E

Tropical Depression 26W

TD 26W began as a very large area of convection over the southern Philippines and tracked northward through the center of the country. The highest winds occurred on the periphery of the circulation, indicating a monsoon depression. A Tropical Cyclone Formation Alert was issued at 171100Z December and indicated numerous small circulations within a large area of convection. The first warning was issued at 171500Z December in the Sibuyan Sea.

TD 26W tracked west-northwestward at 12 to 16 kt and turned northward, passing over central Luzon and into the South China Sea just north of Lingayen Gulf. TD 26W failed to consolidate and intensify due to vertical shear and inflow disruption caused by the mountainous terrain of the Philippine Islands. The cyclone rapidly weakened during the transit over Luzon and the last warning was issued at 190300Z December.

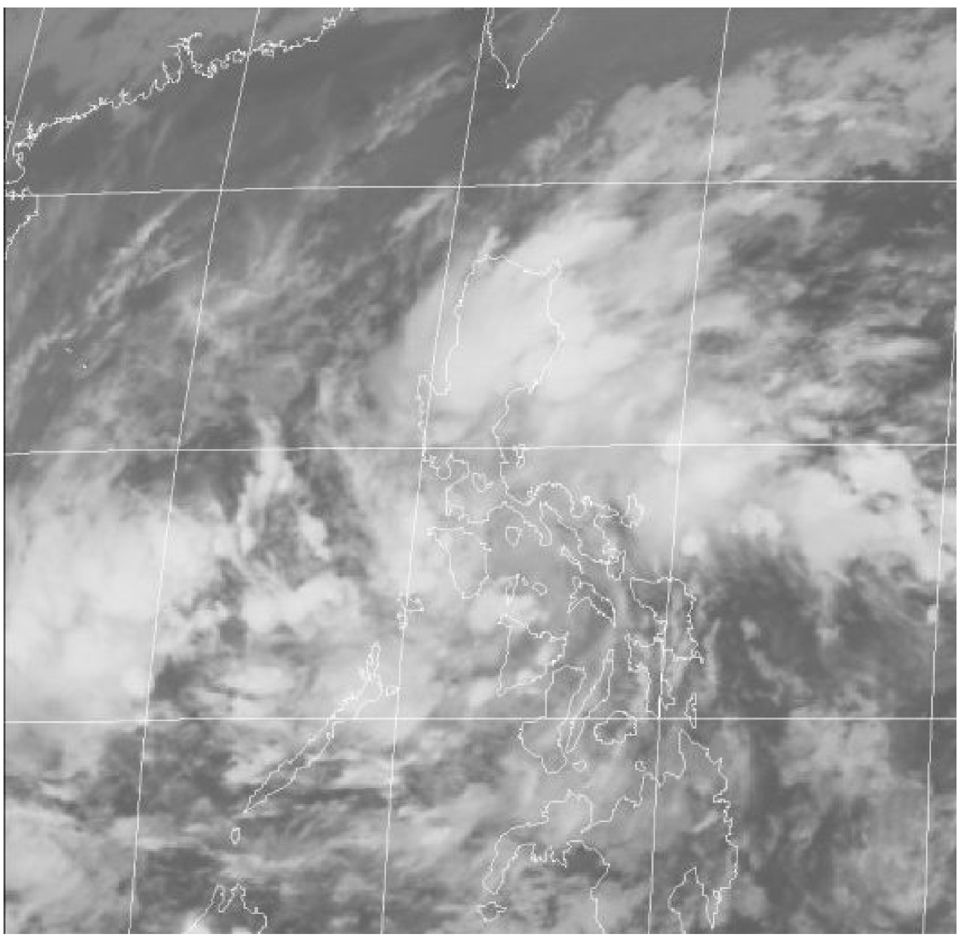
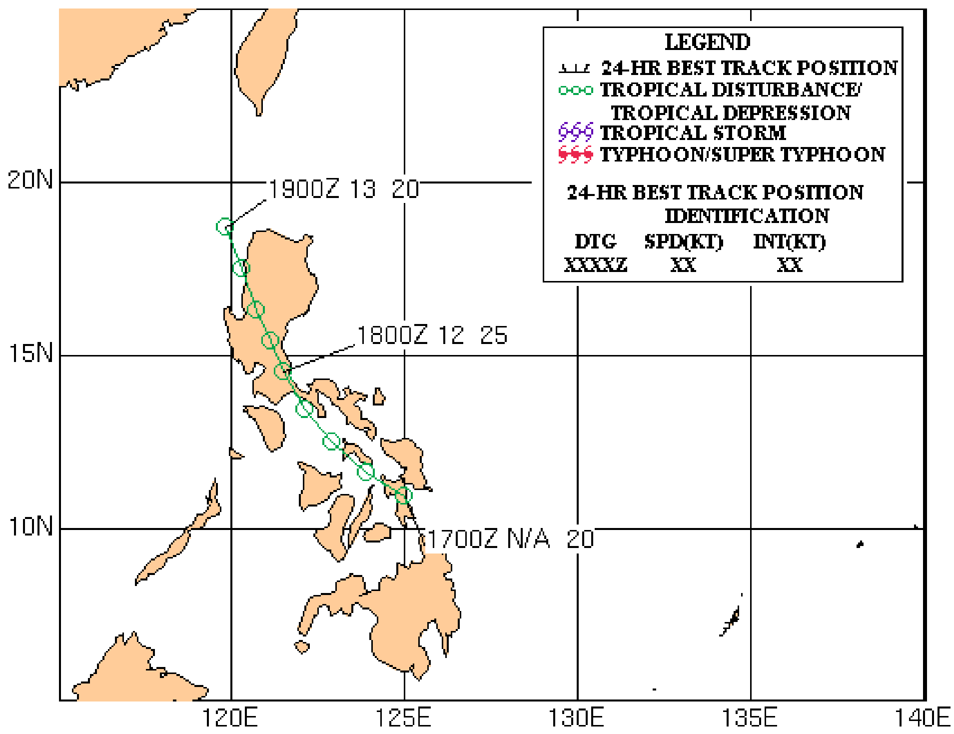


Figure 3-26-1. 171132Z December infrared satellite image with TD 26W located in the Sibuyan Sea.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
1900Z 13 20
1800Z 12 25
1700Z N/A 20
20N
15N
10N
120E
125E
130E
135E
140E

Tropical Depression 27W

TD 27W was a poorly organized tropical cyclone, which failed to develop due to unfavorable environmental conditions. This cyclone formed from a loosely organized cluster of convection in the central South China Sea, with maximum winds along the periphery of the circulation. Like TD 26W, TD 27W experienced a slight increase in organization and then a steady state with a 30 kt intensity for about 24 hours, then weakened and dissipated in the South China Sea.

The first warning was issued at 190900Z December and forecast northwest movement toward Vietnam with maximum winds of 40 kt. The cyclone drifted north to northeastward at 3 to 6 kt during the first 18 hours. TD 27W had a poorly defined low-level circulation center with disorganized convection and subsequently failed to consolidate and organize any further. During this initial period, the cyclone accelerated slightly on the northeastward track while maintaining a 30-knot intensity. The cyclone turned more east-northeastward and weakened as it moved into a greater vertical wind shear environment associated with strong mid to upper tropospheric westerly flow. JTWC issued the final warning at 220300Z December as the cyclone dissipated in the South China Sea just south of Pratas Island.

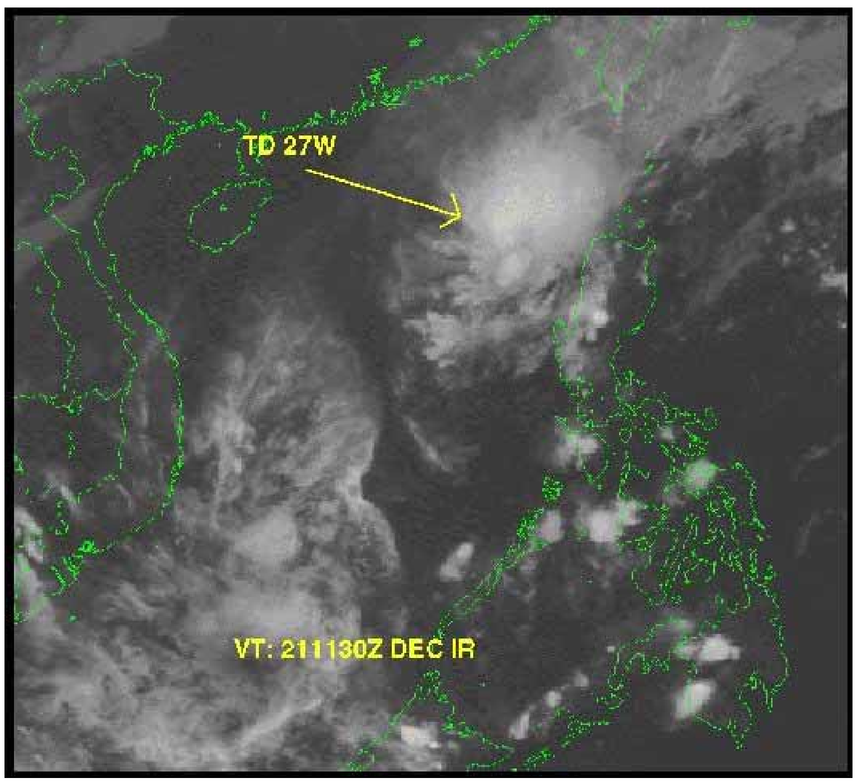
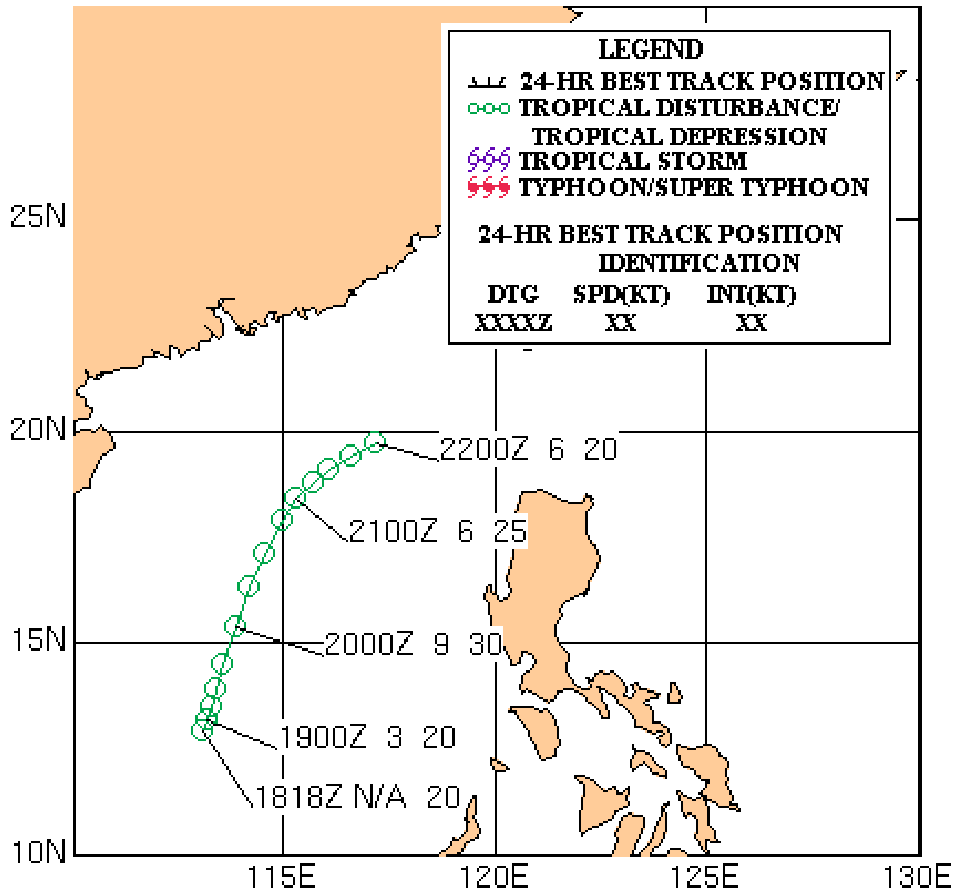


Figure 3-27-1. 211130Z December infrared satellite imagery depicting TD 27W about 12 hours prior to final warning.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
25N
20N
15N
10N
115E
120E
125E
130E
2200Z 6 20
2100Z 6 25
2000Z 9 30
1900Z 3 20
1818Z N/A 20

Tropical Cyclone 01B

The first North Indian Ocean tropical cyclone, TC (01B), of 1998 developed in the southern Bay of Bengal in mid May. The weak tropical disturbance tracked toward southern India before turning northeastward toward Bangladesh. The disturbance reached tropical cyclone strength and peaked at 70 kt just before landfall in Bangladesh.

TC 01B developed from a weak, broad circulation in the near-equatorial trough southeast of Sri Lanka, India on 18 May. The cyclone moved northward for 24 hours, before turning westward toward the northern tip of Sri Lanka. As the cyclone became more organized, it moved northeastward toward Bangladesh. A TCFA was issued at 171600Z May and the first warning was issued at 180900Z May. The cyclone reached a maximum intensity of 70 kt at 200000Z May, just prior to landfall near Chittagong, Bangladesh.

The Associated Press reported that TC 01B ravaged the low-lying Bangladesh coast killing at least 12 people and destroying thousands of homes. A Chittagong Port Authority official reported a fully loaded oil tanker was damaged in a collision with another ship in the storm. A fishing boat and trawler were also caught in the high winds and seas and capsized.

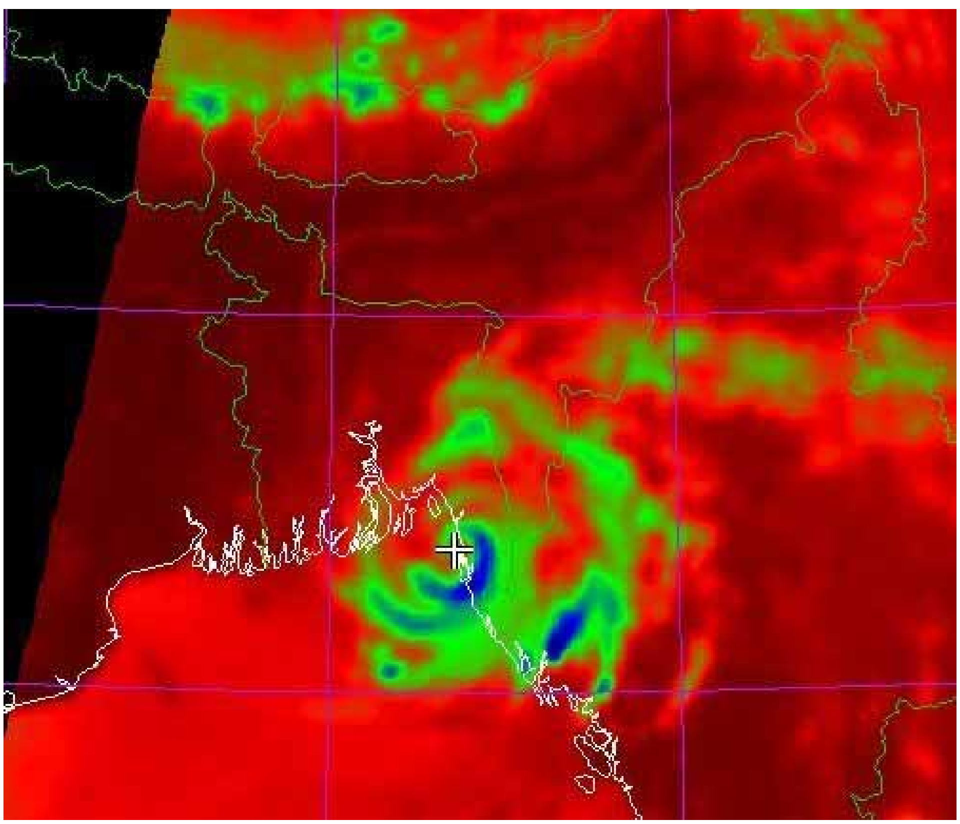
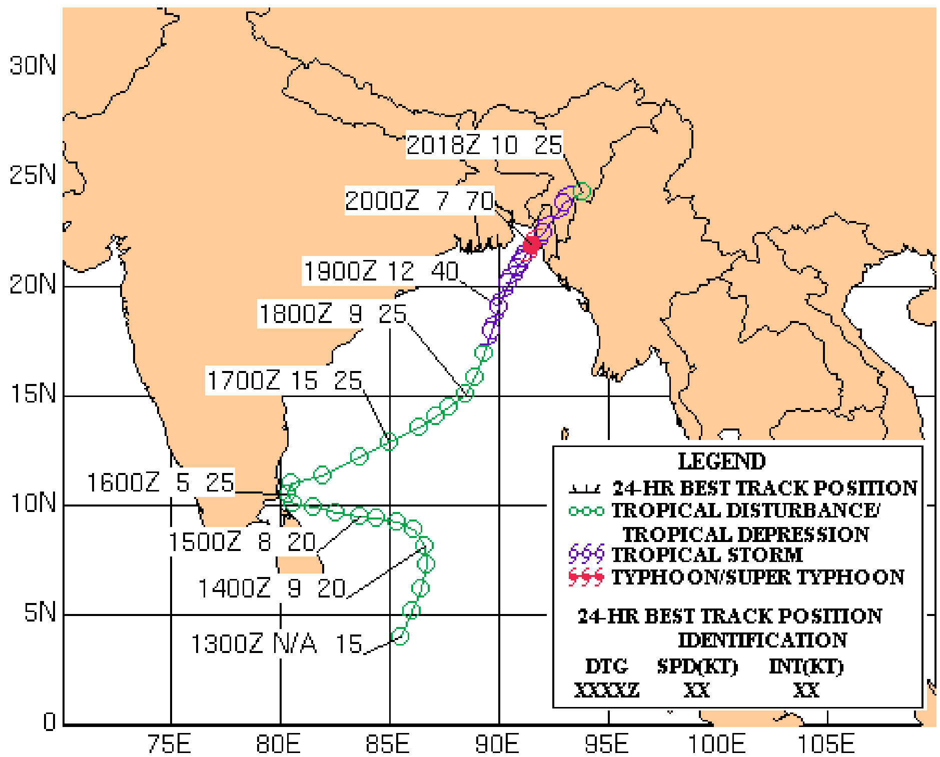


Figure 3-01B-1. 85 GHz SSM/i image at 200113Z May as TC 01B made landfall at its max intensity.


30N
25N
20N
15N
10N
5N
0
75E
80E
85E
90E
95E
100E
105E
2018Z 10 25
2000Z 7 70
1900Z 12 40
1800Z 9 25
1700Z 15 25
1600Z 5 25
1500Z 8 20
1400Z 9 20
1300Z N/A 15
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX

Tropical Cyclone 02A

TC 02A was a short-lived tropical cyclone that developed in the Arabian Sea in late May. This cyclone existed for about 48 hours and during that period reached a maximum intensity of 35 kt while moving slowly toward the west-northwest.

The first warning was issued at 280300Z May. Moderate vertical windshear in the Arabian Sea inhibited the system's development, which peaked at 35 kt. JTWC issued the final warning on this cyclone at 290300Z May as it dissipated over water.

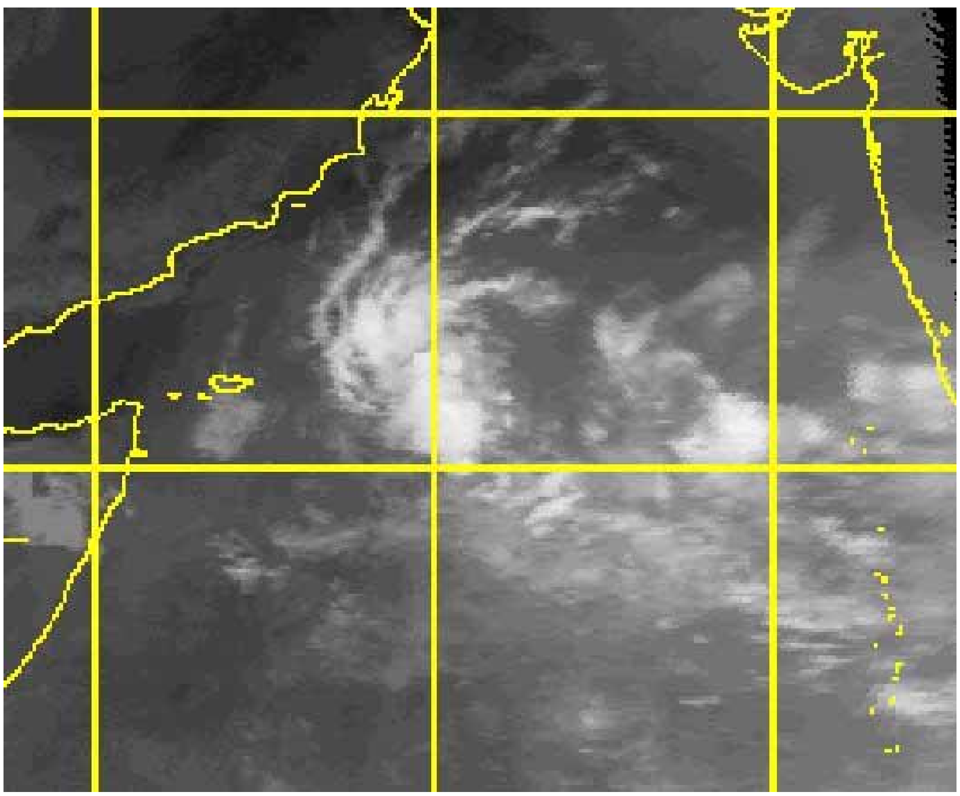
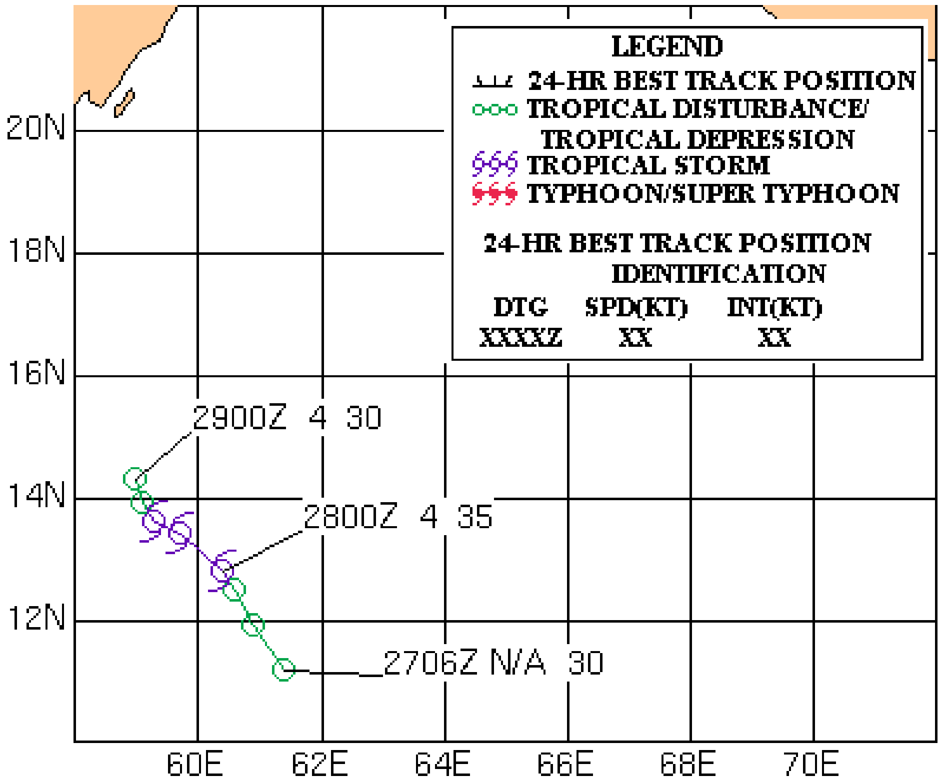


Figure 3-02A-1. Tropical Cyclone 02A undergoing vertical wind shear at its peak intensity of 35 kt. This Meteosat-5 infrared image is from 0300 on 28 May. The system dissipated over water within 24 hours of this image.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/ TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
2900Z 4 30
2800Z 4 35
2706Z N/A 30
20N
18N
16N
14N
12N
60E
62E
64E
66E
68E
70E

Tropical Cyclone 03A

Tropical Cyclone 03A, the most intense tropical cyclone to strike India in 25 years, formed off the southwest tip of India early in June. The storm tracked westward over the Arabian Sea, then turned north and moved inland near Porbandar, India. TC 03A attained a maximum intensity of 105 kt, just prior to making landfall.

JTWC issued a Tropical Cyclone Formation Alert at 030200Z June for an area of convection in the Lacadive Islands. This area of convection continued to organize, and JTWC issued the first warning on TC 03A at 040300Z June.

The cyclone initially tracked slowly west-northwestward away from the Indian coast in response to steering flow of a mid-level ridge located to the northeast. TC 03A accelerated and moved more northward in response to an approaching mid-level trough. The altered synoptic pattern enhanced the outflow from TC 03A and the cyclone intensified and reached maximum intensity of 105 kt as it turned north-northeastward toward India.

TC 03A made landfall in India's western state of Gujarat at 090130Z June. JTWC issued the final warning at 091500Z June due to rapid dissipation over land.

The damage caused by the most intense tropical cyclone to strike India in 25 years was extensive. The NASA sponsored Dartmouth Flood Observatory reported 1126 fatalities in the Guarat, Kutch, Surashtra regions of India with heavy flooding of coastal highways. Homes near the Kandla port were submerged by a two meter tidal wave. The Dartmouth Flood Observatory further reported the drowning of many salt workers in these regions. Over 15,000 people were dislocated as thousands of houses were damaged or destroyed. Total damage estimates were nearly 290 million dollars.

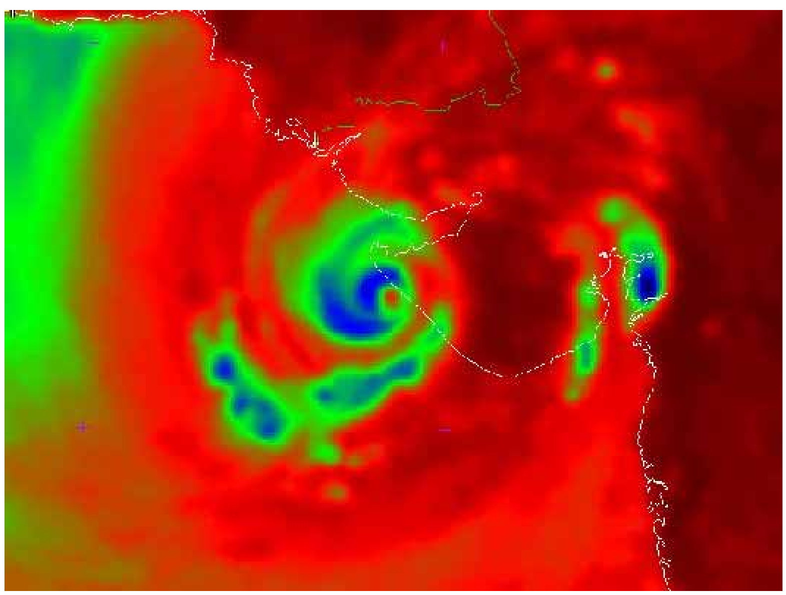


Figure 3-03A-1. An 0137Z Special Sensor Microwave Imager depiction of TC 03A as it made landfall over India as a 105 kt system on the 9th of June, 1998.

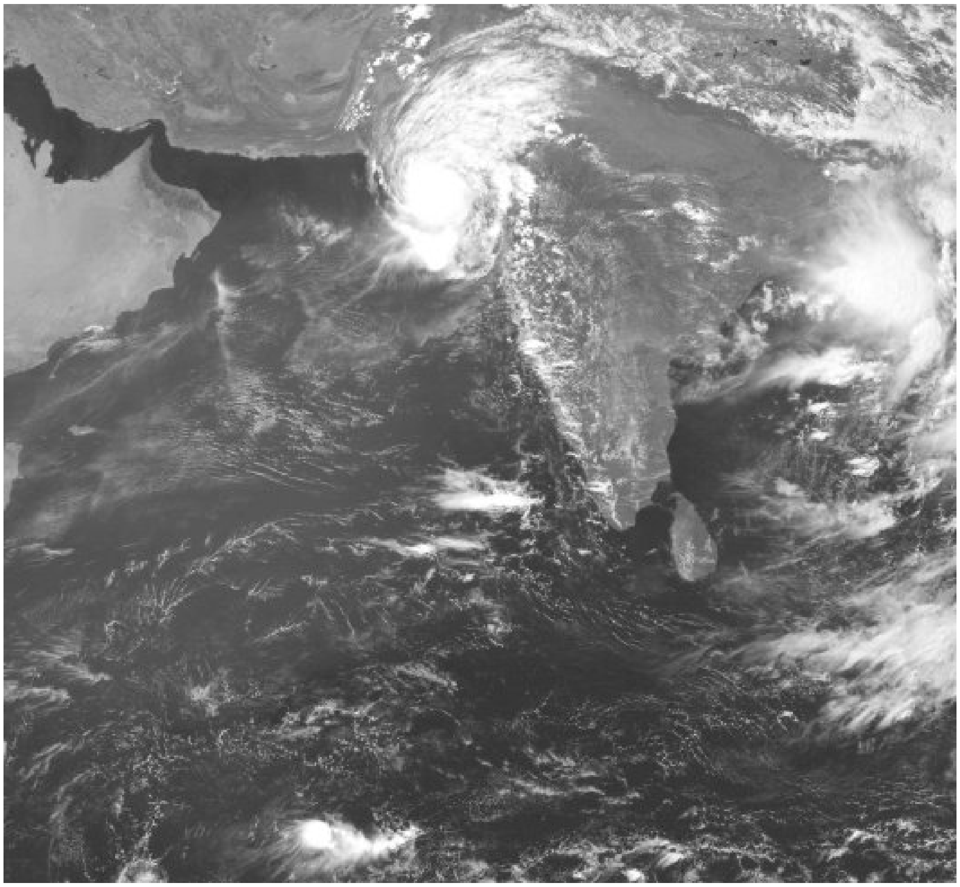
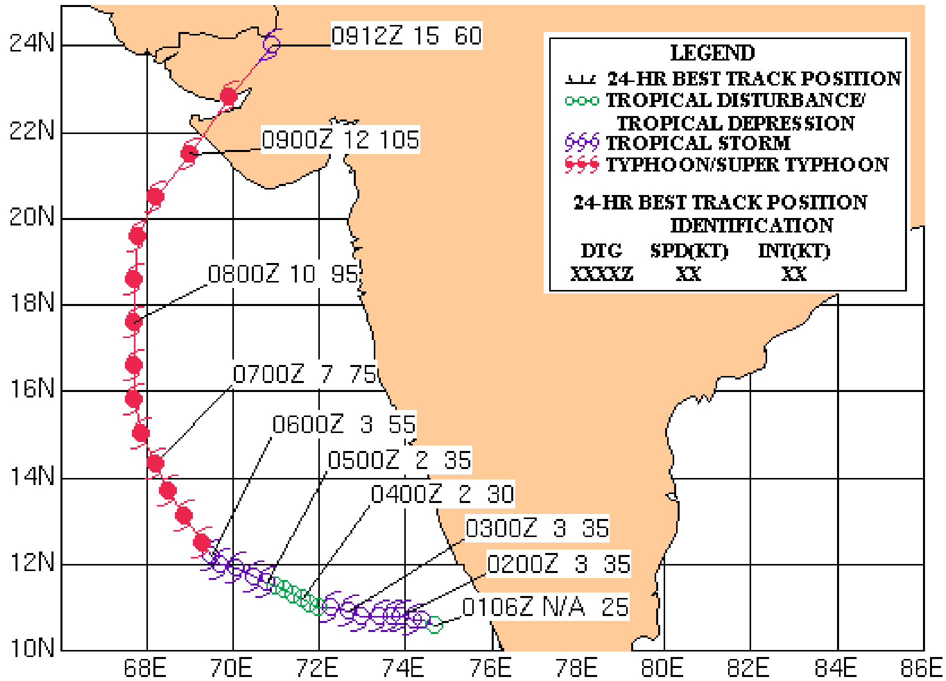


Figure 3-03A-2. An 0900Z visible satellite image of TC 03A just making landfall in Northwestern India on the 9th of June, 1998.



LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/ TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
0912Z 15 60
0900Z 12 105
0800Z 10 95
0700Z 7 75
0600Z 3 55
0500Z 2 35
0400Z 2 30
0300Z 3 35
0200Z 3 35
0106Z N/A 25
24N
22N
20N
18N
16N
14N
12N
10N
68E
70E
72E
74E
76E
78E
80E
82E
84E
86E

Tropical Cyclone 04A

Tropical Cyclone 04A was a short-lived system that developed in the Arabian Sea in late September, then tracked west and quickly dissipated after reaching a peak intensity of 35 kt.

Tropical Cyclone 04A formed in a east-west oriented surface trough in the Arabian Sea, 400 nm west of Bombay in late September. It moved slowly west while developing slowly within a moderate vertical wind shear environment.

JTWC issued the first warning at 300300Z September when the cyclone had a maximum intensity of 35 kt. After the first warning, TC 04A moved west at 10 kt under the steering influence of a mid-level ridge located to the north. TC 04A did not intensify beyond the initial warning intensity of 35 kt due to increased vertical wind shear. TC 04A weakened to 30 kt, and the final warning was issued at 010300Z October.

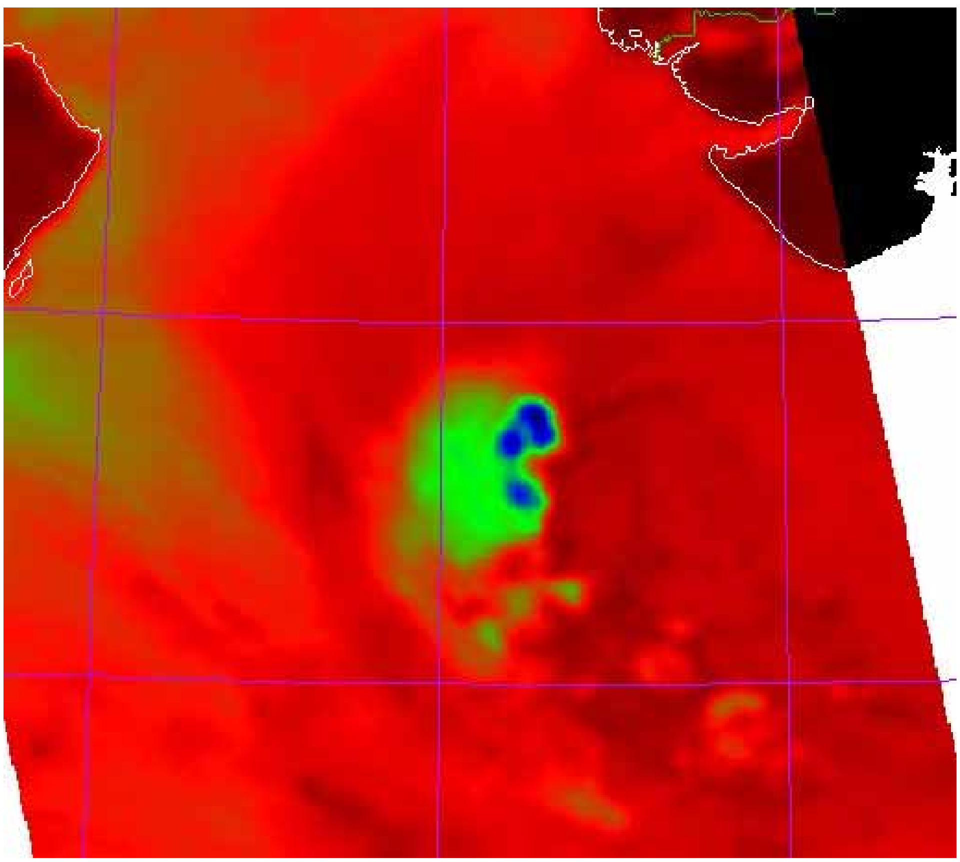


Figure 3-04A-1. 291444Z Special Sensor Microwave Imager depiction of TC 04A as it crossed the Arabian Sea on the 29th of September.

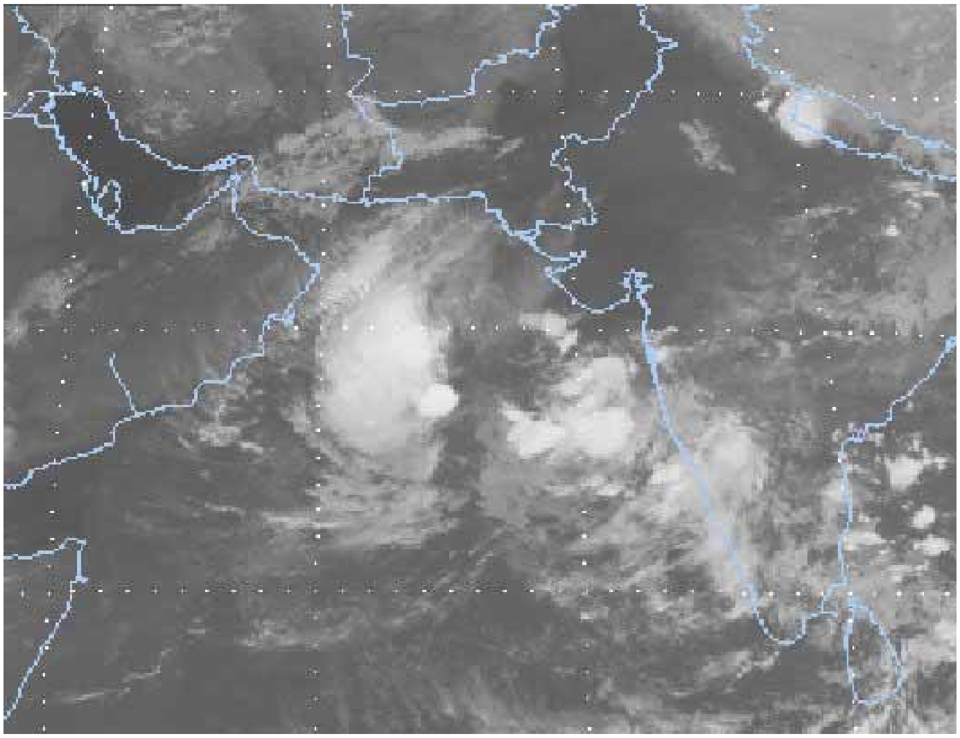
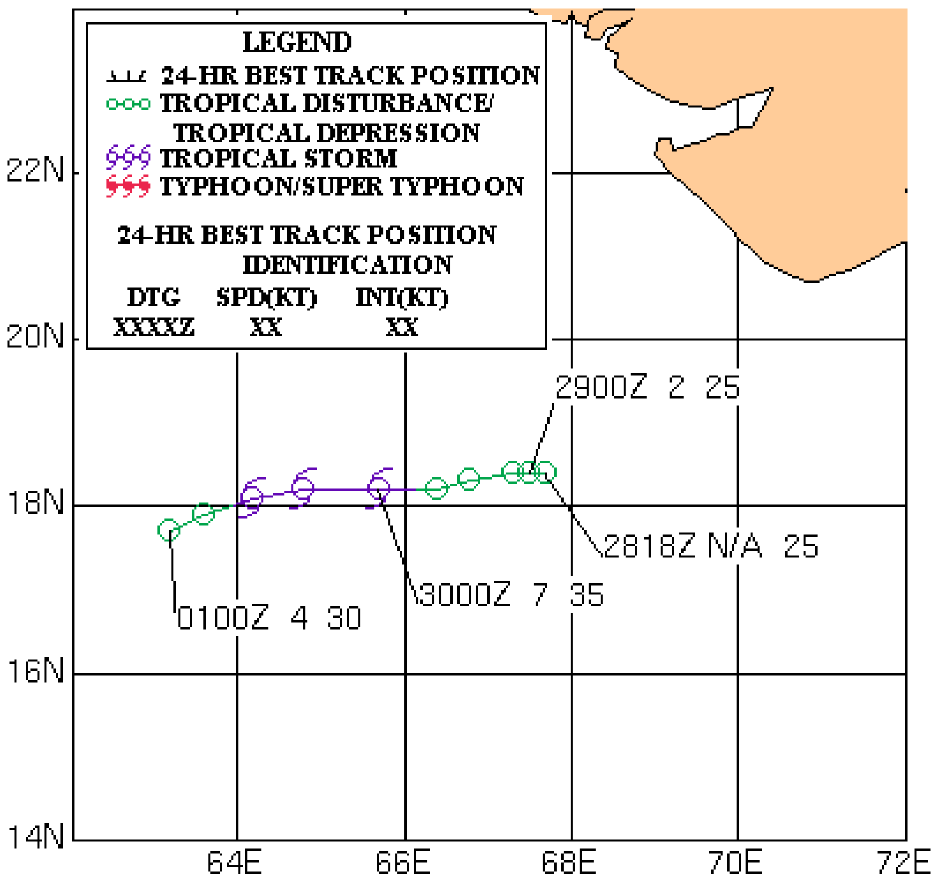


Figure 3-04A-2. A 300000Z September infrared satellite image of TC 04A at its maximum intensity of 35 kt.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/ TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
2900Z 2 25
2818Z N/A 25
3000Z 7 35
0100Z 4 30
22N
20N
18N
16N
14N
64E
66E
68E
70E
72E

Tropical Cyclone 05A

TC 05A formed in the Arabian Sea west of the Laccadive Islands in mid-October. The system tracked east, then northeast and made landfall at Gujarat, India as a 30 kt system. TC 05A was a minimal tropical cyclone with a peak intensity of 35 kt.

TC 05A began as a weak area of low pressure drifting slowly toward India. A TCFA was issued at 150900Z October, based on an ERS-2 scatterometer pass indicating 25 kt winds associated with the low-level circulation center. Despite moderate vertical wind shear limiting the organization of significant deep convection, JTWC issued the first warning at 160300Z October, based on a second scatterometer pass indicating winds of 35 kt.

Vertical wind shear over the tropical cyclone continued to inhibit further development as the system tracked northeast and accelerated slightly in response to environmental steering provided by mid-level ridging to the south. Although TC 05A was tracking toward the same area of India devastated in June by TC 03A, strong vertical wind shear dissipated most of the deep convection reducing the cyclone's intensity. Maximum sustained winds at landfall were 30 kt. JTWC issued its fifth and final warning at 180300Z October as the cyclone dissipated over land.

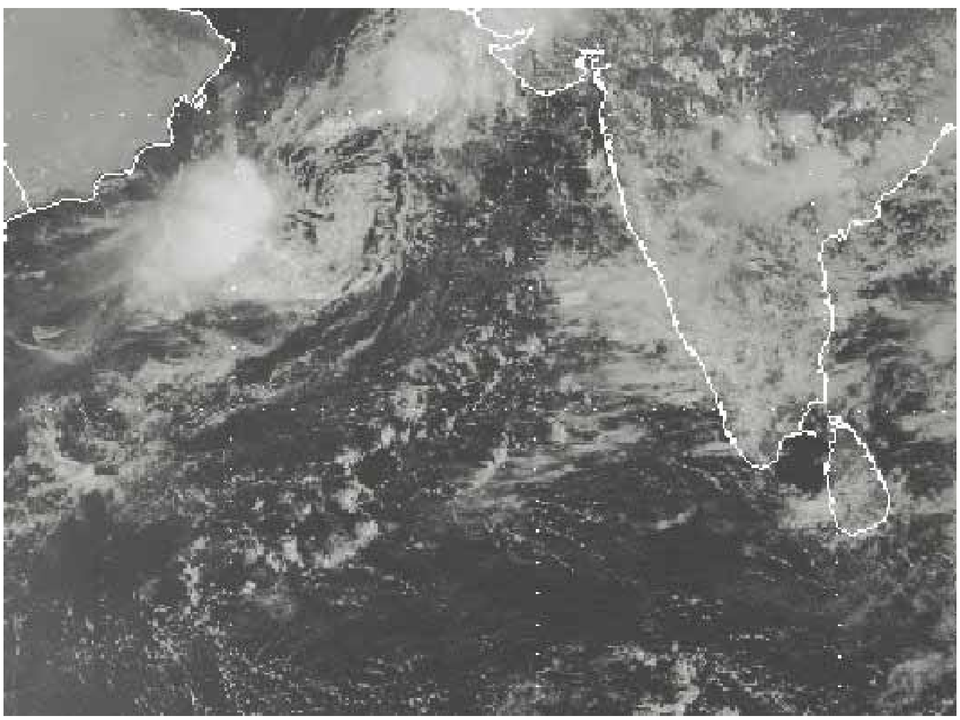


Figure 3-05A-1. An 100000Z Meteosat-5 visible image shows TC 05A under the influence of vertical wind shear on the 15th of October, 1998.

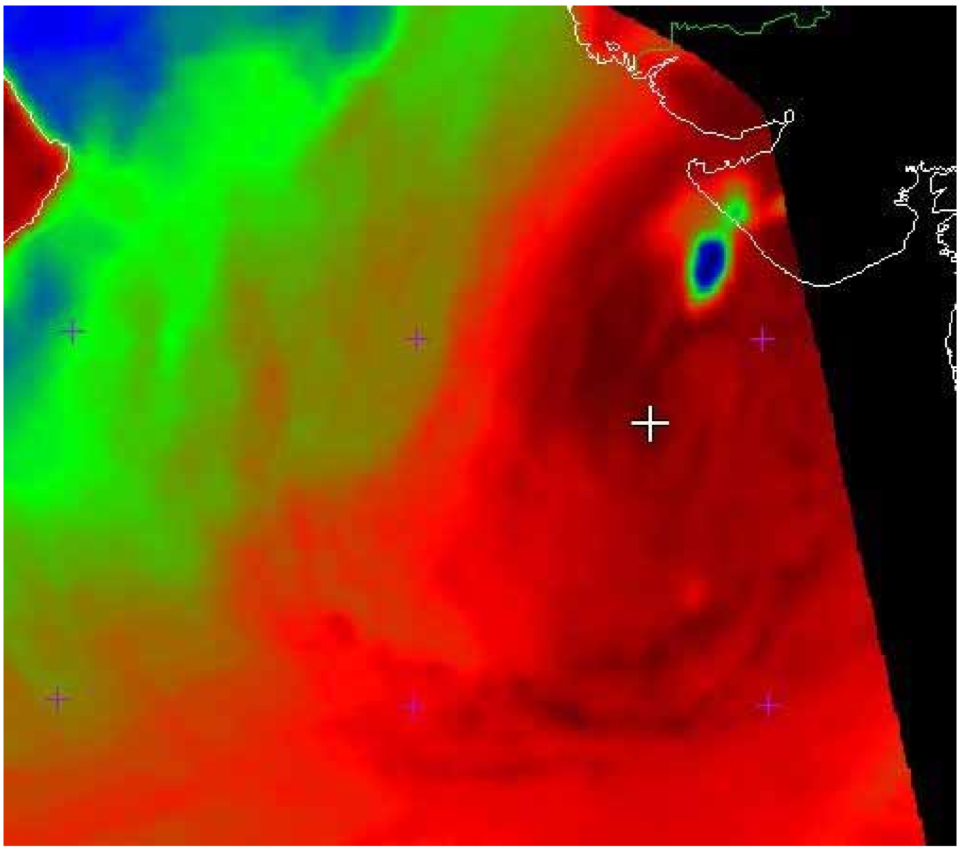
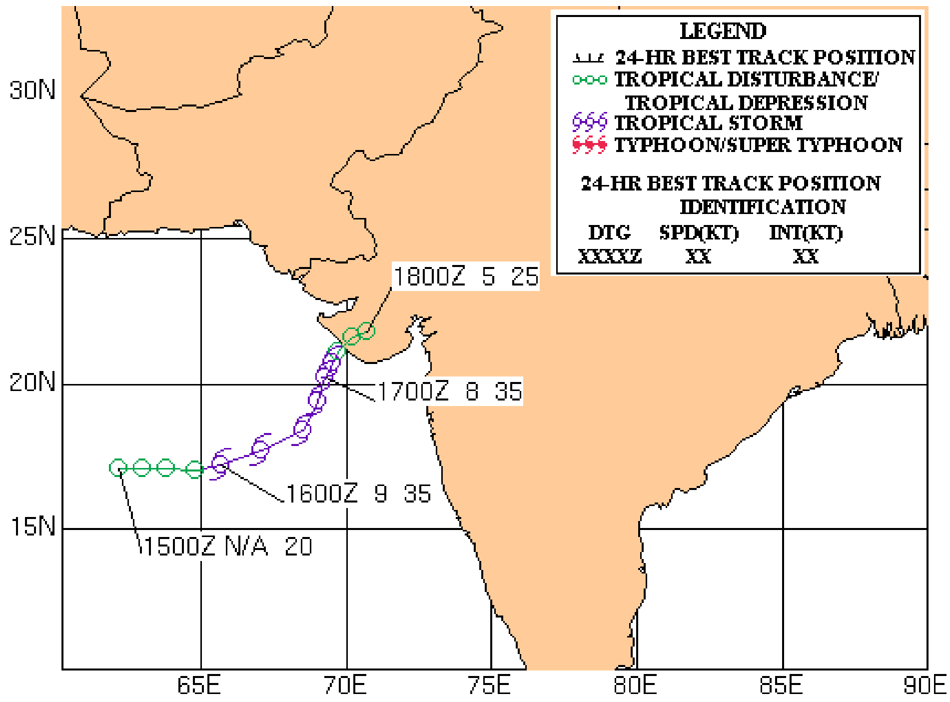


Figure 3-05A-2. A 130700Z microwave image of TC 05A southwest of the northwestern India on the 16th of October, 1998.



LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
1800Z 5 25
1700Z 8 35
1600Z 9 35
1500Z N/A 20
30N
25N
20N
15N
65E
70E
75E
80E
85E
90E

Tropical Cyclone 06B

Tropical Cyclone 06B formed in the Bay of Bengal in mid-November then tracked northwestward into east-central India and attained peak intensity of 85 kt just prior to landfall. The cyclone subsequently dissipated rapidly while moving north into central India.

A Tropical Cyclone Formation Alert was issued at 130630Z November. JTWC issued the first warning at 140300Z November as a 40 kt system.

TC 06B tracked steadily northwestward at speed of 8 to 13 knots while intensifying. The cyclone attained a maximum intensity of 85 knots at 151200Z November, just before making landfall 30 nm southwest of Visakhapatnam, India. TC 06B quickly dissipated over land and JTWC issued the final warning at 160300Z November.

According to RSMC Darwin's Monthly Report, TC 06B cause two deaths and extensive crop and property damage in India.

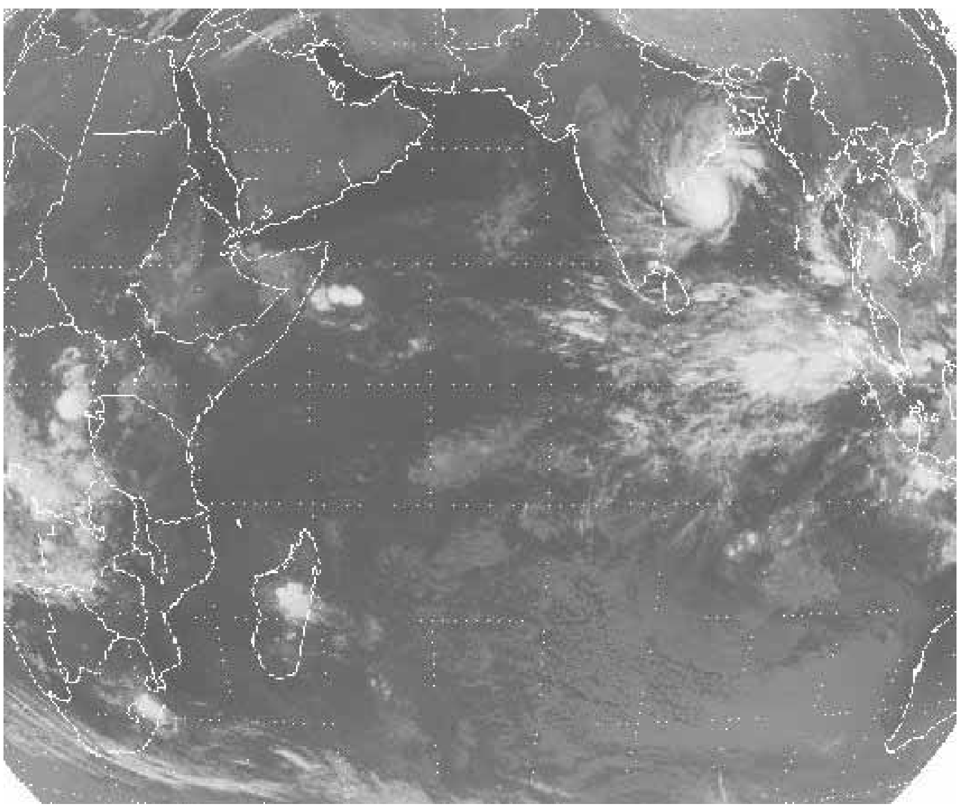
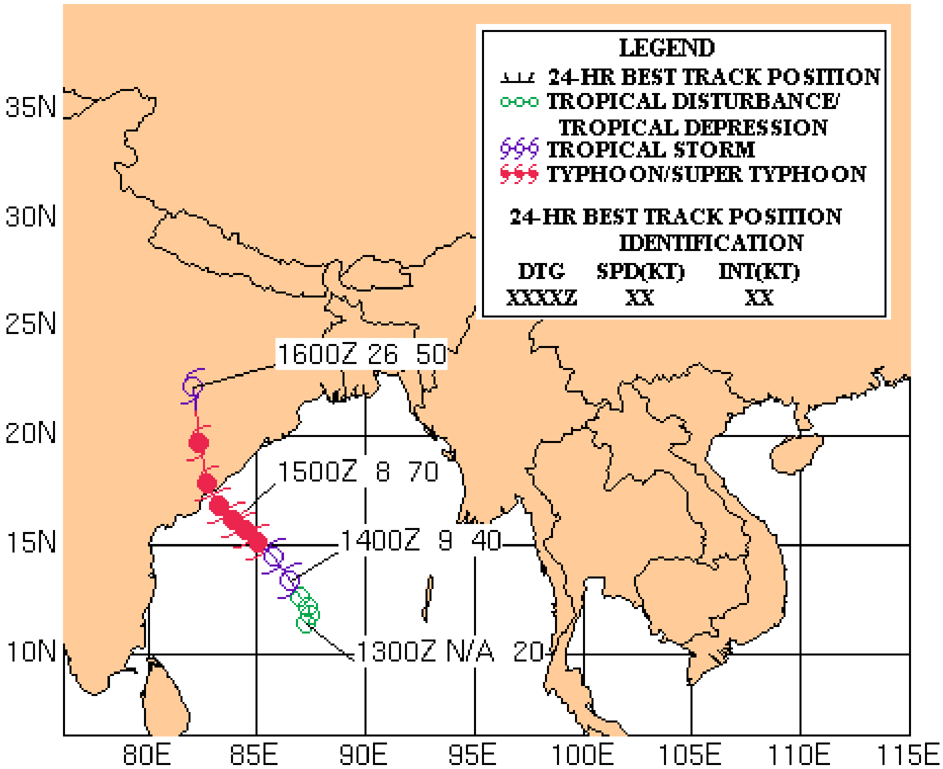


Figure 3-06B-1. Meteosat-5 depiction of TC 06B at 2030Z on the 14th of November, 1998 while TC 06B was a 70 kt system. TC 06B intensified to an 85 kt system within 12 hours.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG
SPD(KT)
INT(KT)
XXXXZ
XX
XX
1600Z 26 50
1500Z 8 70
1400Z 9 40
1300Z N/A 20
35N
30N
25N
20N
15N
10N
80E
85E
90E
95E
100E
105E
110E
115E

Tropical Cyclone 07B

TC 07B formed from the remnants of TS Chip (21W). TS Chip dissipated over Vietnam on 15 November, and then tracked over Vietnam, into the Gulf of Thailand, westward across the Malay Peninsula, and into the Andaman Sea. As the remnants of TS Chip moved into the Bay of Bengal, JTWC began to issue warnings on this cyclone as TC 07B. TC 07B developed steadily in the Bay of Bengal, peaking at 75 kt on 220000Z November. TC 07B then weakened, making landfall in Bangladesh at minimal tropical storm intensity.

The first TCFA was issued on 180130Z November. Two more TCFA's were issued while the developing cyclone was under the influence of significant vertical windshear. The first warning was issued at 200300Z November with sustained winds of 35 kt. TC 07B initially tracked northwestward at 12 kt, briefly slowed to 5 kt, and then accelerated to 10 kt while intensifying. By 220000Z November, TC 07B reached a maximum intensity of 75 kt.

TC 07B began its turn northeastward as it moved along the western periphery of the subtropical ridge. During this northward movement, the vertical windshear increased dramatically, and weakened the system, displacing the deep convection to the northeast. TC 07B was a 35 kt system when it made landfall over Bangladesh (30 nm southwest of Bavisa). After making landfall, the cyclone dissipated and JTWC issued the final warning at 230300Z November.

The storm surge associated with TC 07B caused coastal communities in Bangladesh to be inundated. More than 100 fishermen were reported lost.

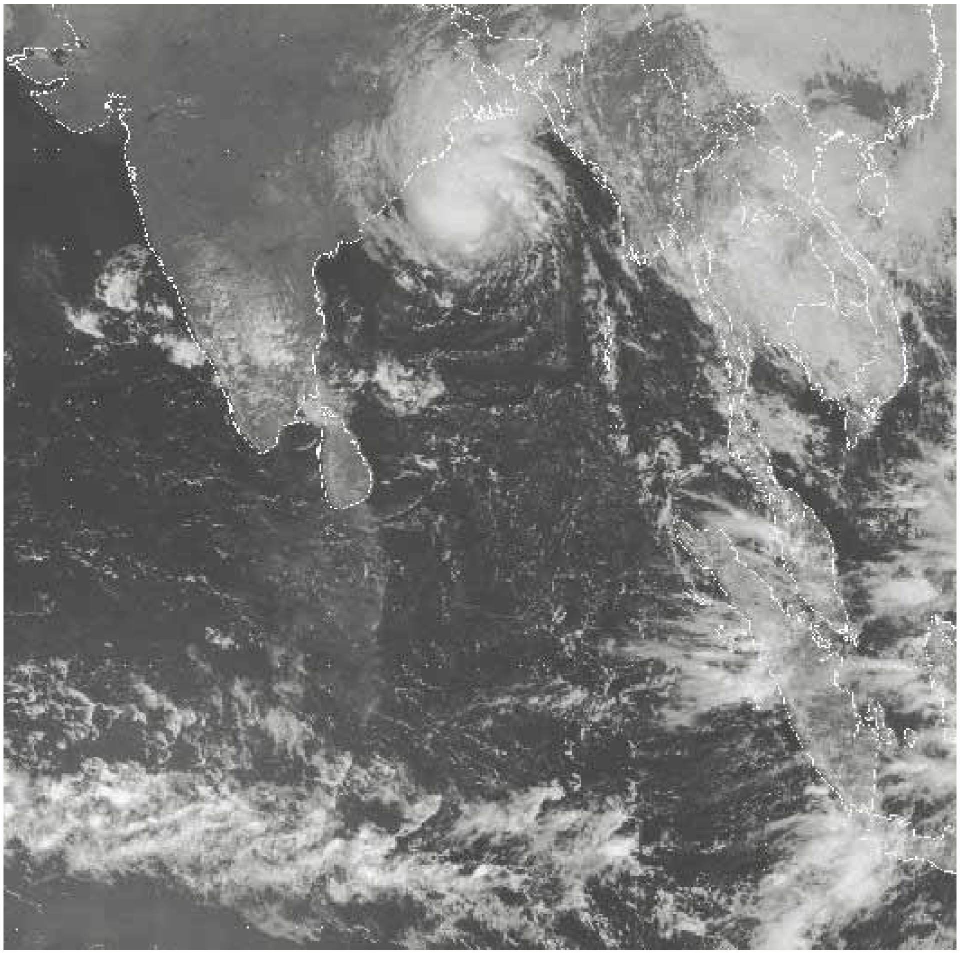
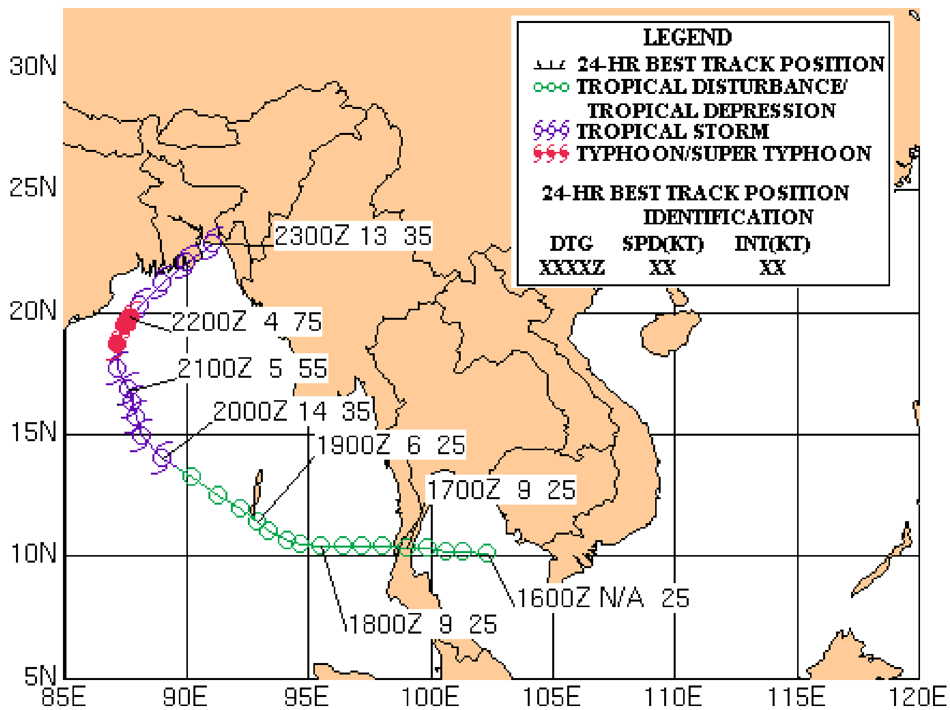


Figure 3-07B-1. Meteosat-5 visible imagery 210630Z November. TC 07B as a 60 kt system approaching the coast of India.


LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG
SPD(KT)
INT(KT)
XXXXZ
XX
XX
2300Z 13 35
2200Z 4 75
2100Z 5 55
2000Z 14 35
1900Z 6 25
1700Z 9 25
1600Z N/A 25
1800Z 9 25
30N
25N
20N
15N
10N
5N
85E
90E
95E
100E
105E
110E
115E
120E

Tropical Cyclone 08A

TC 08A developed slowly but attained a maximum intensity of 65 kt as it tracked across the Arabian Sea over a 6 day period before making landfall and dissipating over Oman.

TC 08A formed in the Laccadive Islands off the southwest tip of India in December. A TCFA was issued on 11 December and the first warning was issued at 130300Z December as the system drifted west-northwest at 3 kt.

On 131800Z December, TC 08A turned northward and accelerated as it continued to intensify. TC 08A reached its maximum intensity of 65 kt on 150600Z December, while tracking north-northwestward at 7 kt.

Dry air entrainment from the Arabian Peninsula and increased vertical wind shear weakened the cyclone. Subsequently, the convection was pushed to the northeast as the low-level circulation turned west on 160000Z December.

Although partially exposed, the low-level circulation remained tightly wound as TC 08A tracked westward. The cyclone made landfall in Oman at 170600Z December with maximum winds of 35 kt. After landfall, the cyclone rapidly weakened and the final warning was issued at 171500Z December.

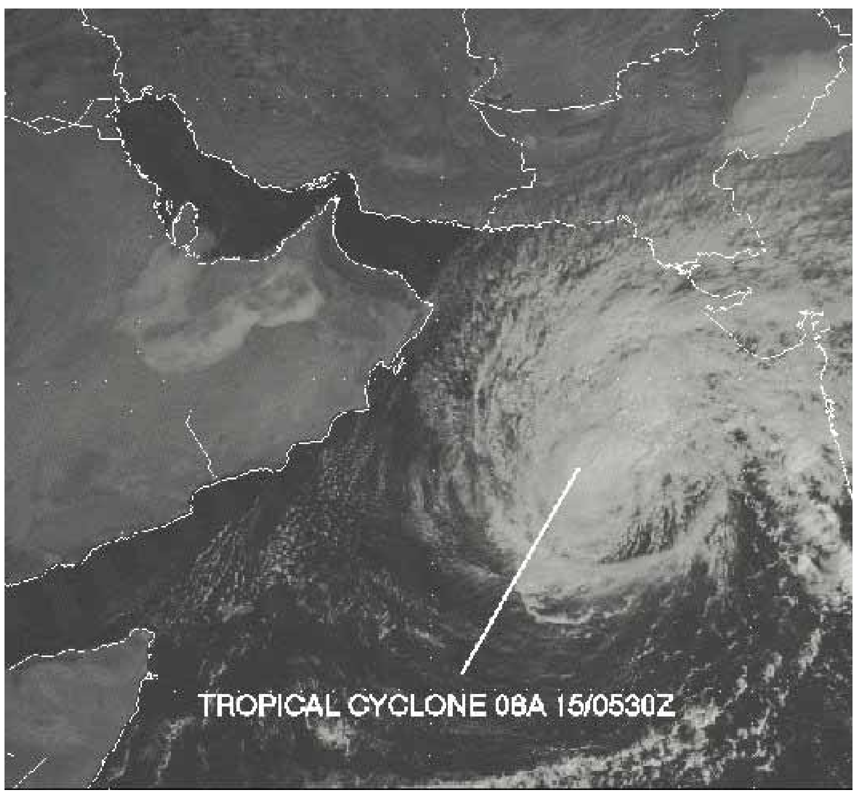
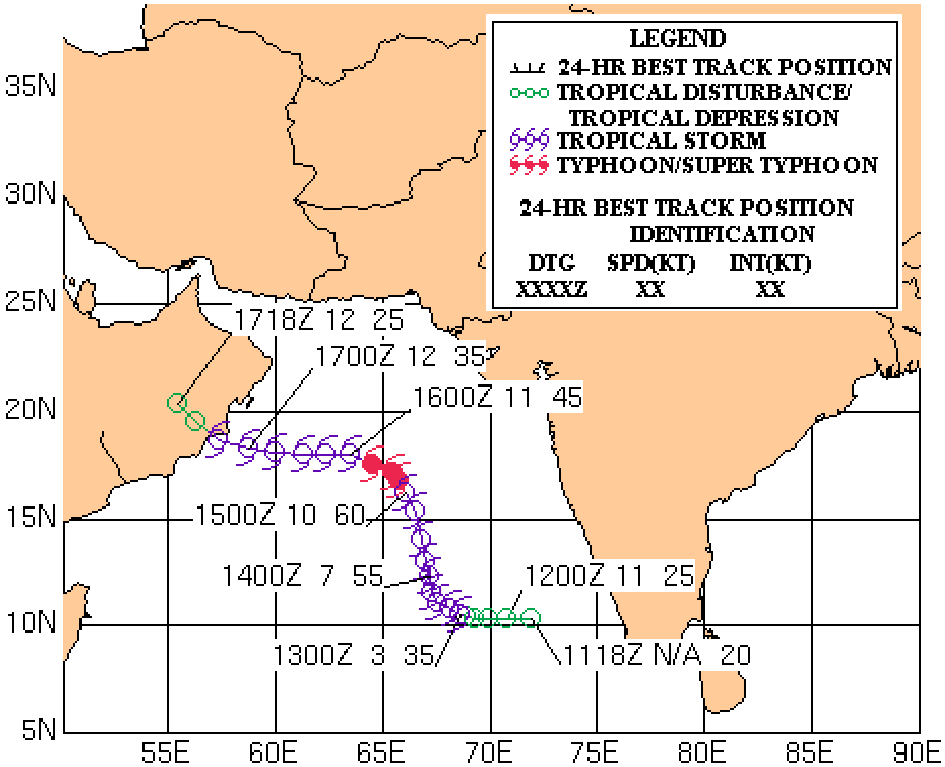


Figure 3-08A-1. Meteosat-5 visible imagery during TC 08A's peak intensity (65 kt).



LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XX
1718Z 12 25
1700Z 12 35
1600Z 11 45
1500Z 10 60
1400Z 7 55
1300Z 3 35
1200Z 11 25
1118Z N/A 20
35N
30N
25N
20N
15N
10N
5N
55E
60E
65E
70E
75E
80E
85E
90E

Chapter 4
South Pacific And South Indian Ocean Tropical Cyclones

4.1 GENERAL

In accordance with CINCPACINST 3140.1W, Southern Hemisphere tropical cyclones are numbered sequentially from 1 July through 30 June to encompass the period when the majority of the Southern Hemisphere tropical cyclones have occurred.

JTWC's Southern Hemisphere Area of Responsibility extends from 180 longitude, westward to the coast of Africa. For warning message delineation, JTWC's Southern Hemisphere AOR is subdivided into two basins; the South Indian (west of 135 East longitude) and the South Pacific Ocean (east of 135 East longitude). The suffixes "S" (South Indian Ocean) and "P" (South Pacific Ocean) are appended to the tropical cyclone number to differentiate warnings for these basins.

The Operations Department of NAVPACMETOCCEN, Pearl Harbor, Hawaii issues warnings for South Pacific Ocean tropical cyclones east of 180 longitude.

4.2 SUMMARY

The total number of significant tropical cyclones during the 1998 season (Table 4-1) was 37 which was approximately 9 more than the climatological mean of 28.4 (Table 4-2).

A comparison of the 1998 tropical cyclone activity for the 3 Southern Hemisphere sub-basins against climatology. (Table 4-3 indicates that tropical cyclone activity was "normal" for the southern Indian Ocean and Australian basins, and nearly 3 times more active in the South Pacific.)

Composites of the tropical cyclone best tracks for the Southern Indian Ocean appear in Figures 4-1a, 4-1b, 4-2a, 4-2b, 4-3a, 4-3b and 4-3c.

Table 4-1 SOUTHERN HEMISPHERE TROPICAL CYCLONES FOR 1998 01 JULY 1997 - 30 JUNE 1998

TC	NAME	PERIOD	NUMBER ISSUED	EST MAX SFC WINDS KTS (M/SEC)	MSLP (MB)
01S	-	20 JUL 24 JUL	13	45 (23)	991
02P	LUSI	10 OCT 12 OCT	7	55 (28)	984
03P	-	26 OCT 29 OCT	4	35 (18)	997
*04P	MARTIN	30 OCT 04 NOV	(11)	100 (51)	944
05P	NUTE	18 NOV 20 NOV	6	70 (36)	972
*06P	OSEA	23 NOV 28 NOV	(8)	90 (46)	954
*07P	PAM	05 DEC 09 DEC	(8)	65 (33)	976
08S	SID	26 DEC 28 DEC	6	40 (21)	994
09S	SELWYN	27 DEC 01 JAN	11	65 (33)	976
*10P	RON	02 JAN 08 JAN	(14)	145 (75)	892
11P	SUSAN	03 JAN 10 JAN	13	140 (72)	898
12P	KATRINA	03 JAN 25 JAN	44	90 (46)	954
13S	-	18 JAN 22 JAN	11	35 (18)	997
14P	LES	24 JAN 01 FEB	22	50 (25)	987
15S	TIFFANY	24 JAN 31 JAN	19	120 (62)	922
*16P	TUI	25 JAN 26 JAN	(3)	40 (21)	994
*17P	URSULA	01 FEB 02 FEB	(2)	65 (33)	976
*18P	VELI	01 FEB 03 FEB	(4)	75 (39)	967
*19P	WES	01 FEB 04 FEB	(7)	45 (23)	991
20S	ANACELLE	08 FEB 13 FEB	16	115 (59)	927
21S	-	09 FEB 09 FEB	2	35 (18)	997
22S	VICTOR	10 FEB 18 FEB	24	90 (46)	954
23S	BELTANE	16 FEB 18 FEB	6	40 (21)	994
24S	-	16 FEB 18 FEB	5	45 (23)	991
25P	MAY	25 FEB 26 FEB	2	35 (18)	997
26S	DONALINE	06 MAR 09 MAR	6	55 (28)	984
27S	ELSIE	12 MAR 17 MAR	11	90 (46)	954
28S	FIONA	17 MAR 20 MAR	8	35 (18)	997
29P	YALI	18 MAR 27 MAR	24	90 (46)	954
30P	NATHAN	21 MAR 31 MAR	34	65 (33)	976
31P	ZUMAN	30 MAR 05 APR	15	100 (51)	944
32S	GEMMA	07 APR 15 APR	19	70 (36)	972
33S	-	07 APR 07 APR	2	30 (15)	1000
34S	-	19 APR 22 APR	10	40 (21)	994
35S	-	19 APR 19 APR	2	40 (21)	994
*36P	ALAN	22 APR 26 APR	(8)	45 (23)	991
*37P	BART	30 APR 01 MAY	(2)	35 (18)	997
		JTWC TOTAL	342		
		( ) NPMOC TOTAL	(67)		
		GRAND TOTAL	409		

*WARNINGS ISSUED BY NPMOC

Table 4-2 MONTHLY DISTRIBUTION OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES 1981-1998

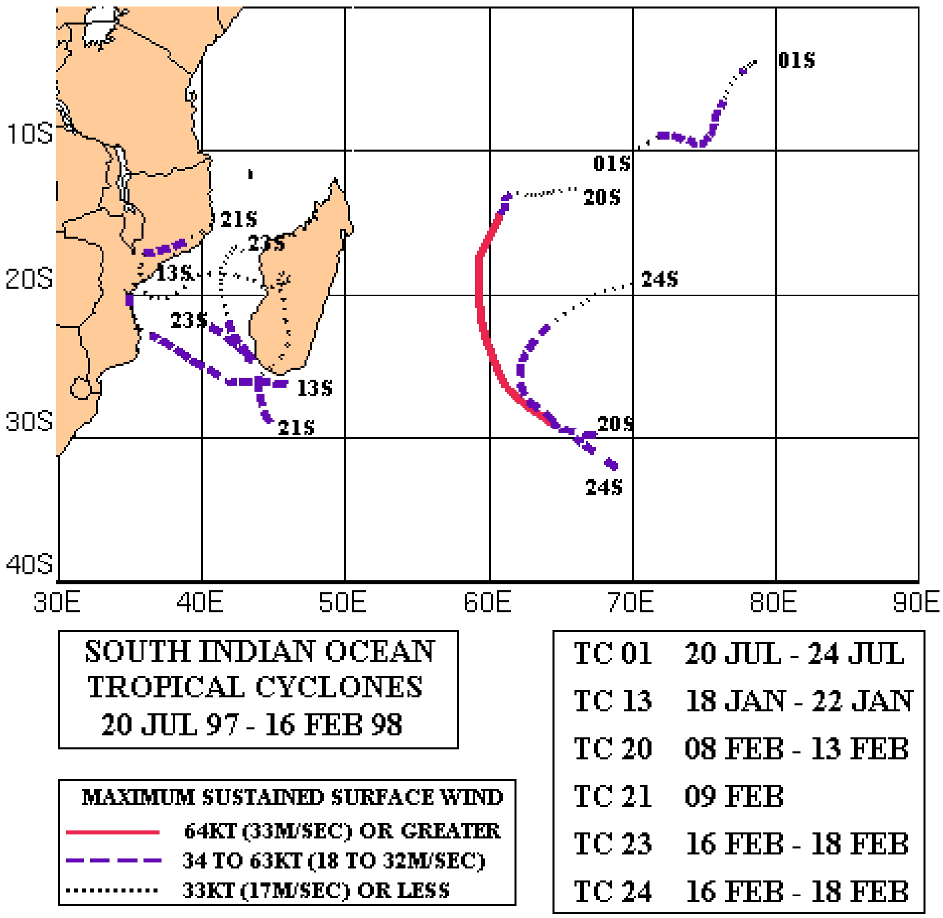
YEAR	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
1958-1977 AVE*	-	-	-	0.4	1.5	3.6	6.1	5.8	4.7	2.1	0.5	-	24.7
1981	0	0	0	1	3	2	6	5	3	3	1	0	24
1982	1	0	0	1	1	3	9	4	2	3	1	0	25
1983	1	0	0	1	1	3	5	6	3	5	0	0	25
1984	1	0	0	1	2	5	5	10	4	2	0	0	30
1985	0	0	0	0	1	7	9	9	6	3	0	0	35
1986	0	0	1	0	1	1	9	9	6	4	2	0	33
1987	0	1	0	0	1	3	6	8	3	4	1	1	28
1988	0	0	0	0	2	3	5	5	3	1	2	0	21
1989	0	0	0	0	2	1	5	8	6	4	2	0	28
1990	2	0	1	1	2	2	4	4	10	2	1	0	29
1991	0	0	1	1	1	3	2	5	5	2	1	1	22
1992	0	0	1	1	2	5	4	11	3	2	1	0	30
1993	0	0	1	1	0	5	7	7	2	2	2	0	27
1994	0	0	0	0	2	4	8	4	9	3	0	0	30
1995	0	0	0	0	2	2	5	4	5	4	0	0	22
1996	0	0	0	0	1	3	7	6	6	4	1	0	28
1997	1	1	1	2	2	6	9	8	3	1	3	1	38
1998	1	0	0	3	2	3	7	9	6	6	0	0	37
TOTAL	7	2	6	13	28	61	2	122	85	55	189	3	512
AVERAGE (1981-1998)	0.4	0.1	0.4	0.7	1.6	3.4	6.2	6.8	4.7	3.0	1.1	0.2	28.4

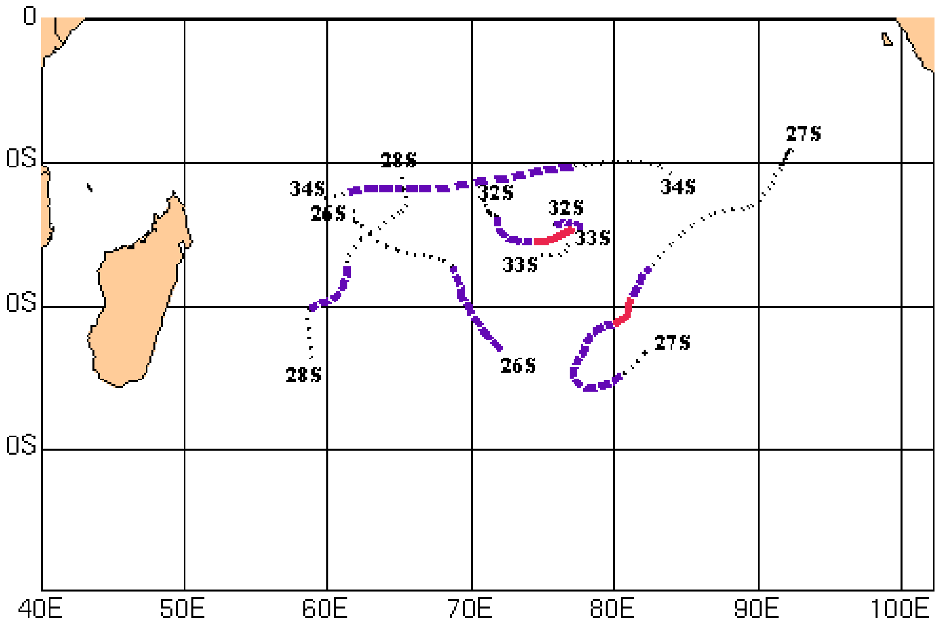
* (Gray, 1978)

Table 4-3 ANNUAL VARIATION OF SOUTHERN HEMISPHERE TROPICAL CYCLONES BY OCEAN BASIN

YEAR	SOUTH INDIAN (WEST OF 105E)	AUSTRALIAN (105E - 165E)	SOUTH PACIFIC (EAST OF 165E)	TOTAL
1958-1977 AVE*	8.4	10.3	5.9	24.6
1981	13	8	3	24
1982	12	11	2	25
1983	7	6	12	25
1984	14	14	2	30
1985	14	15	6	35
1986	14	16	3	33
1987	9	8	11	28
1988	14	2	5	21
1989	12	9	7	28
1990	18	8	3	29
1991	11	10	1	22
1992	11	6	13	30
1993	10	16	1	27
1994	16	10	4	30
1995	11	7	4	22
1996	13	11	4	28
1997	17	5	16	38
1998	12	10	15	37
TOTAL	228	172	102	512
AVERAGE (1981-1998)	12.7	9.6	5.7	28.4

* (Gray,1978)

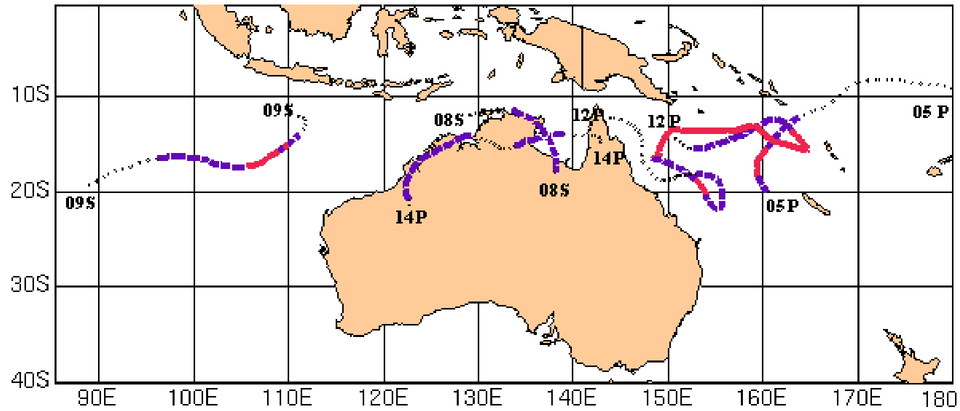

01S
01S
20S
21S
23S
13S
24S
23S
13S
21S
20S
24S
10S
20S
30S
40S
30E
40E
50E
60E
70E
80E
90E
SOUTH INDIAN OCEAN
TROPICAL CYCLONES
20 JUL 97 - 16 FEB 98
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS
TC 01 20 JUL - 24 JUL
TC 13 18 JAN - 22 JAN
TC 20 08 FEB - 13 FEB
TC 21 09 FEB
TC 23 16 FEB - 18 FEB
TC 24 16 FEB - 18 FEB



SOUTH INDIAN OCEAN
TROPICAL CYCLONES
6 MAR 98 - 19 APR 98

MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS

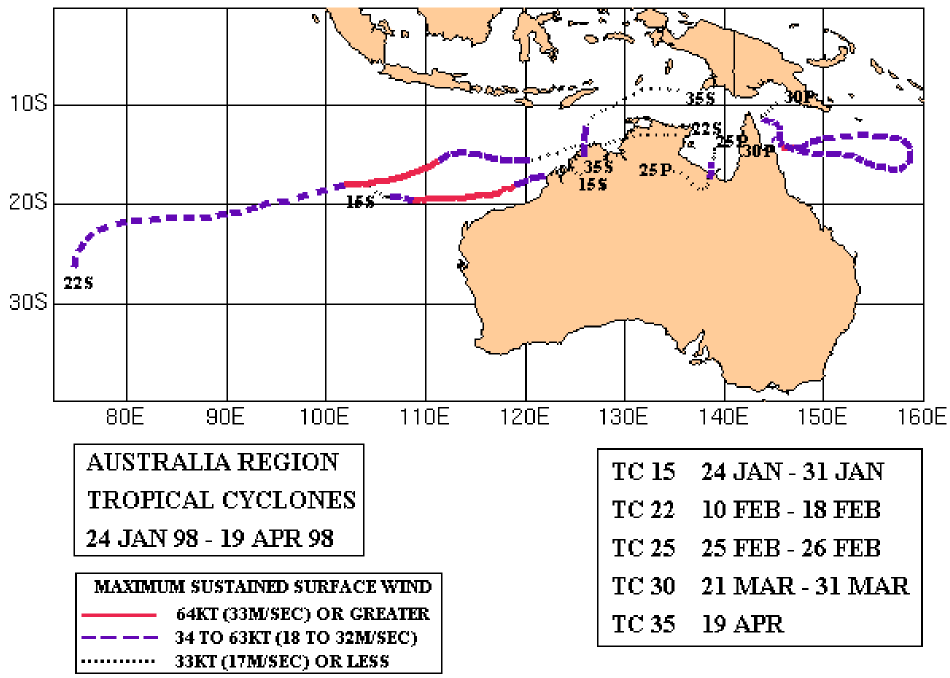
TC 26	06 MAR - 09 MAR
TC 27	12 MAR - 17 MAR
TC 28	17 MAR - 20 MAR
TC 32	07 APR - 15 APR
TC 33	07 APR
TC 34	19 APR - 22 APR

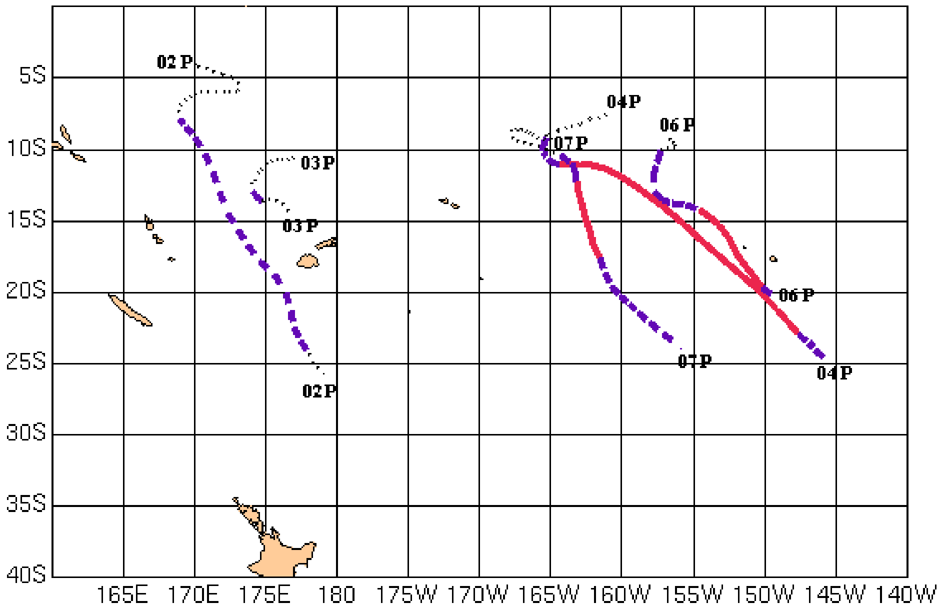


AUSTRALIA REGION
TROPICAL CYCLONES
18 NOV 97 - 24 JAN 98

TC 05	18 NOV - 20 NOV
TC 08	26 DEC - 28 DEC
TC 09	27 DEC - 01 JAN
TC 12	03 JAN - 25 JAN
TC 14	24 JAN - 01 FEB

MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS

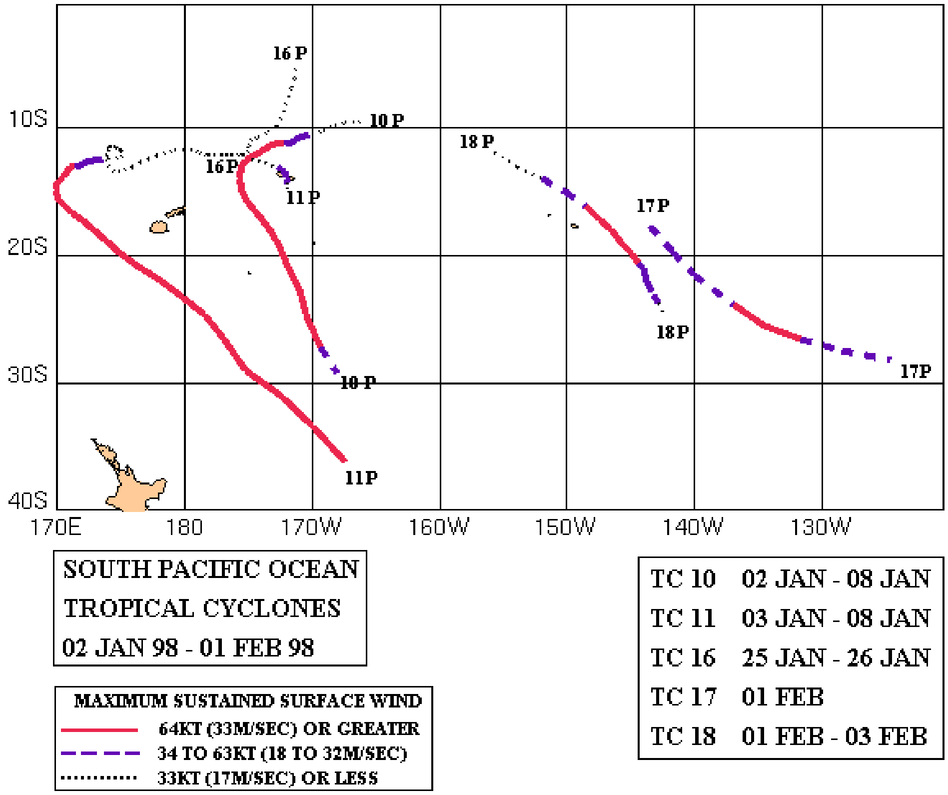

10S
20S
30S
80E
90E
100E
110E
120E
130E
140E
150E
160E
35S
30P
22S
25P
30P
35S
15S
25P
15S
22S
AUSTRALIA REGION
TROPICAL CYCLONES
24 JAN 98 - 19 APR 98
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS
TC 15 24 JAN - 31 JAN
TC 22 10 FEB - 18 FEB
TC 25 25 FEB - 26 FEB
TC 30 21 MAR - 31 MAR
TC 35 19 APR

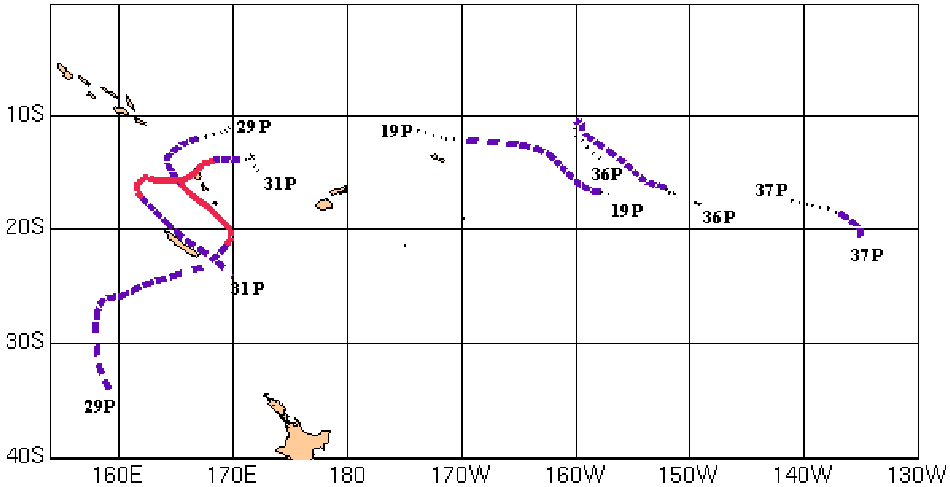


SOUTH PACIFIC OCEAN
TROPICAL CYCLONES
08 OCT 97 - 05 DEC 97

MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS

TC 02	08 OCT - 12 OCT
TC 03	26 OCT - 28 OCT
TC 04	30 OCT - 04 NOV
TC 06	23 NOV 0 26 NOV
TC 07	05 DEC - 09 DEC


16 P
10 P
18 P
16P
11 P
17P
20S
10S
30S
40S
18 P
17P
10 P
11P
170E
180
170W
160W
150W
140W
130W
SOUTH PACIFIC OCEAN
TROPICAL CYCLONES
02 JAN 98 - 01 FEB 98
TC 10 02 JAN - 08 JAN
TC 11 03 JAN - 08 JAN
TC 16 25 JAN - 26 JAN
TC 17 01 FEB
TC 18 01 FEB - 03 FEB
MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS



SOUTH PACIFIC OCEAN
TROPICAL CYCLONES
01 FEB 98 - 30 APR 98

TC 19	01 FEB - 04 FEB
TC 29	18 MAR - 27 MAR
TC 31	30 MAR - 05 APR
TC 36	22 APR - 26 APR
TC 37	30 APR - 01 MAY

MAXIMUM SUSTAINED SURFACE WIND
64KT (33M/SEC) OR GREATER
34 TO 63KT (18 TO 32M/SEC)
33KT (17M/SEC) OR LESS

Chapter 5
Summary Of Forecast Verification

5.1 ANNUAL FORECAST VERIFICATION

Verification of warning positions and intensities at initial, 12-, 24-, 48-, and 72-hour forecast periods was made against the final best track. The (scalar) track forecast, along-track and cross-track errors (illustrated in Figure 5-1) were calculated for each verifying JTWC forecast. These data, in addition to a detailed summary for each tropical cyclone, are included as Chapter 6. This section summarizes verification data for 1998 and contrasts it with annual verification statistics from previous years.

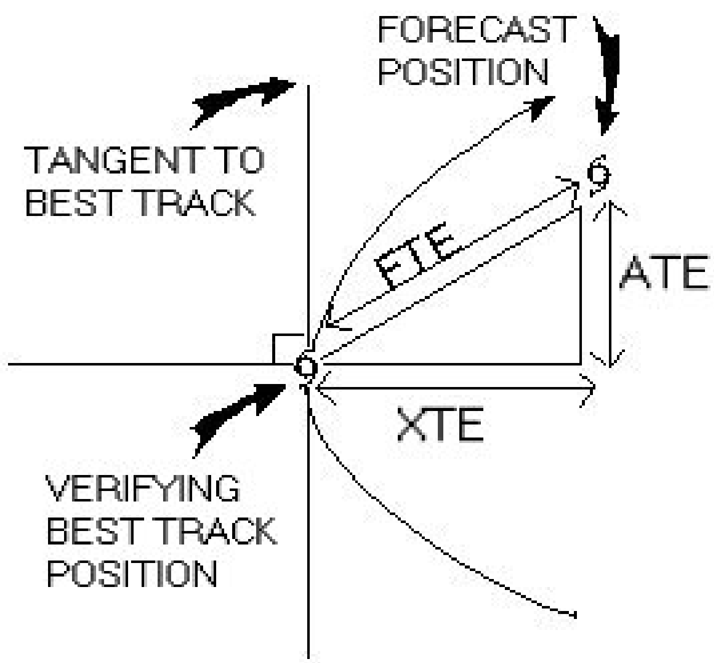


Figure 5-1. Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the forecast position is ahead of and to the right of the verifying best track position. Therefore, the XTE is positive (to the right of the best track) and the ATE is positive (ahead or faster than the best track). Adapted from Tsui and Miller, 1988.

5.1.1 NORTHWEST PACIFIC OCEAN

The frequency distributions of errors for initial warning positions and 12-, 24-, 36-, 48- and 72-hour forecasts are presented in Figures 5-2a through 5-2f. Table 5-1 includes mean track, along-track and cross-track errors for 1984-1998. Figure 5-3 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours since 1974. Table 5-2 lists annual mean track errors from 1959, when JTWC was founded, until the present.

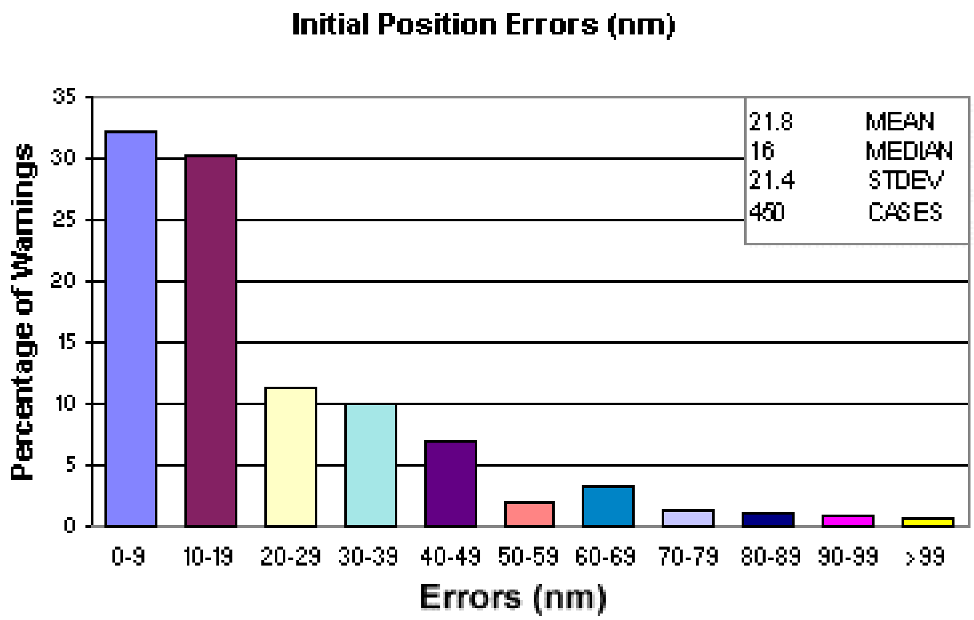


Figure 5-2a. Frequency distribution of initial warning position errors (10 nm increments) for the North West Pacific Ocean tropical cyclones in 1998.

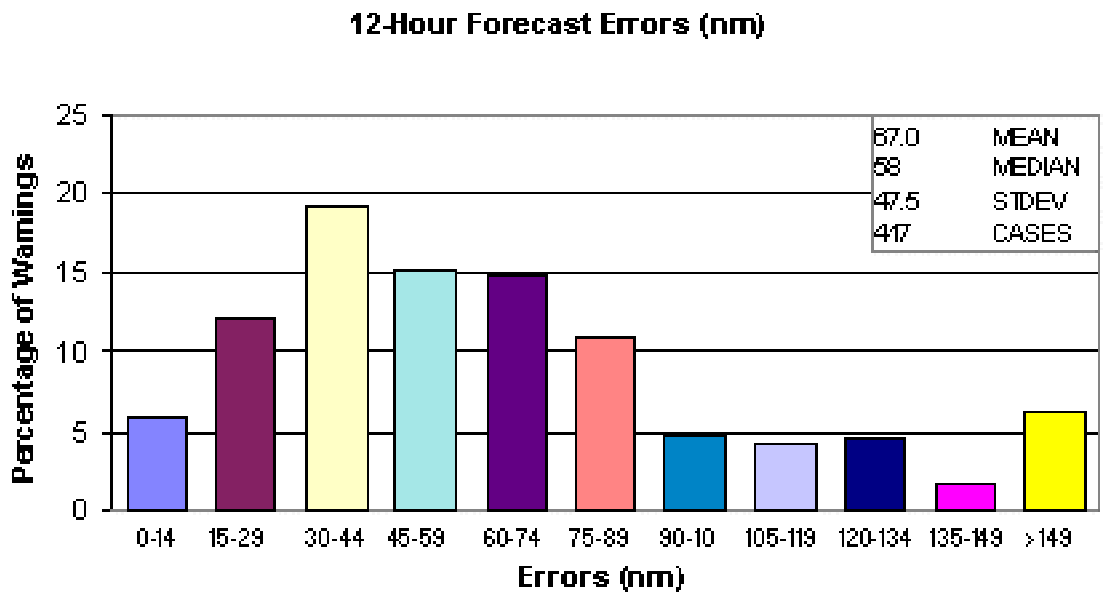


Figure 5-2b. Frequency distribution of 12-hour track forecast errors (15 nm increments) for the North West Pacific Ocean tropical cyclones in 1998.

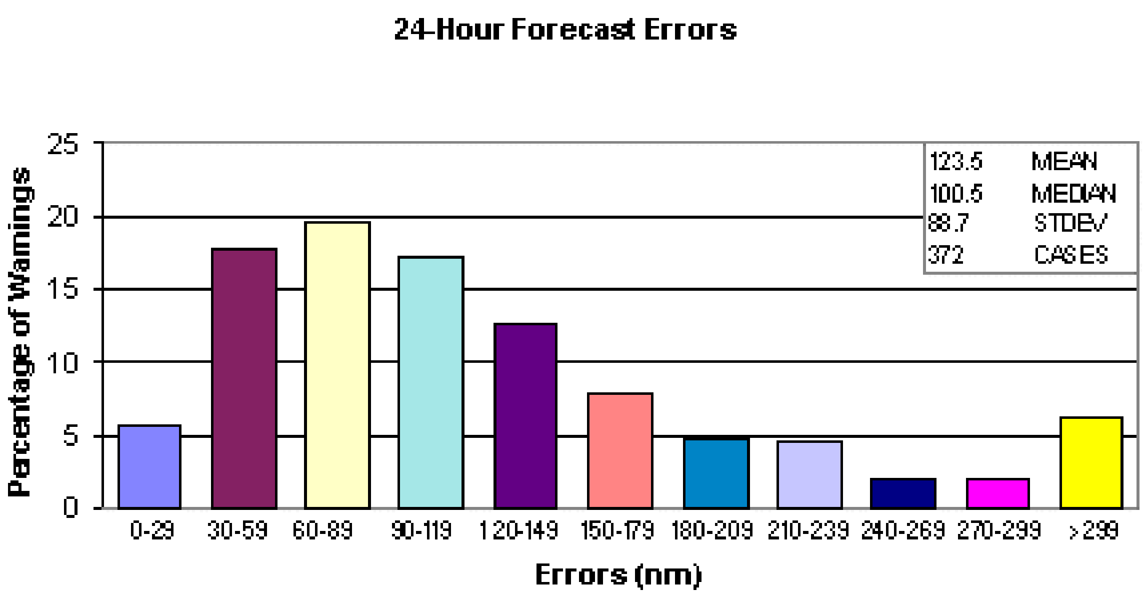


Figure 5-2c. Frequency distribution of 24-hour track forecast errors (30 nm increments) for the North West Pacific Ocean tropical cyclones in 1998.

36-Hour Forecast Errors

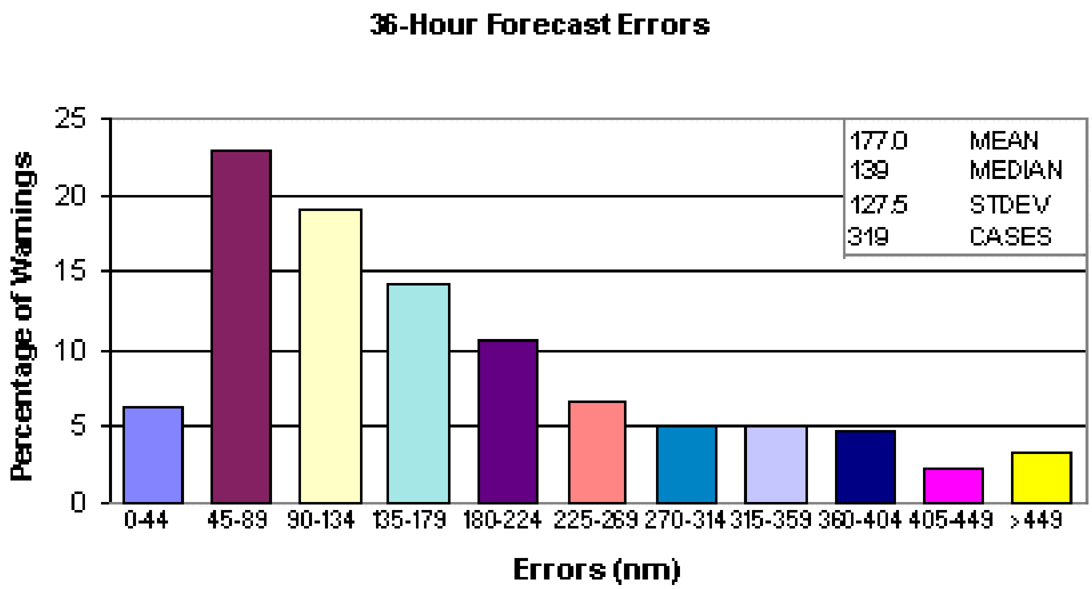


Figure 5-2d. Frequency distribution of 36-hour track forecast errors (45 nm increments) for the North West Pacific Ocean tropical cyclones in 1998.

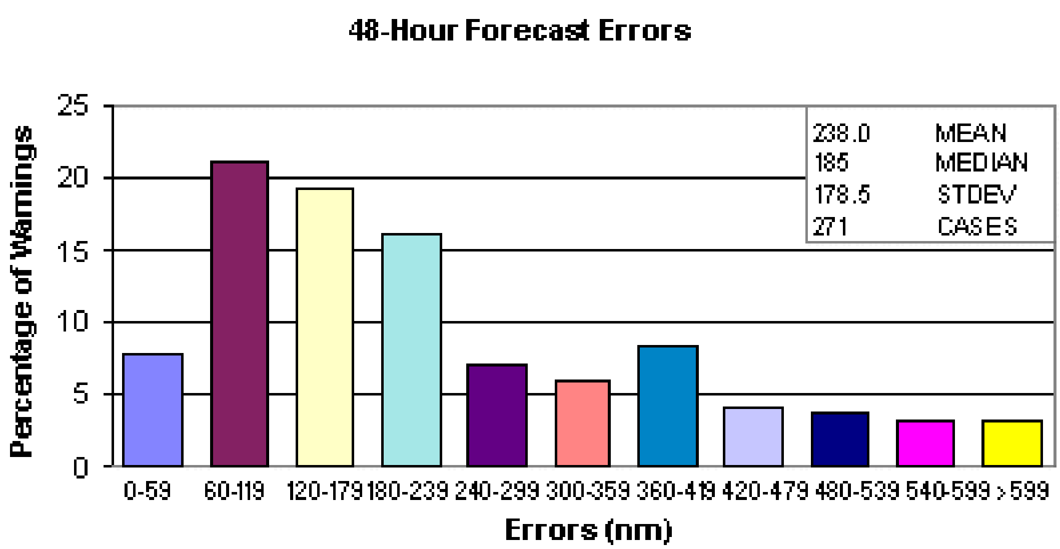


Figure 5-2e. Frequency distribution of 48-hour track forecast errors (60 nm increments) for the North West Pacific Ocean tropical cyclones in 1998.

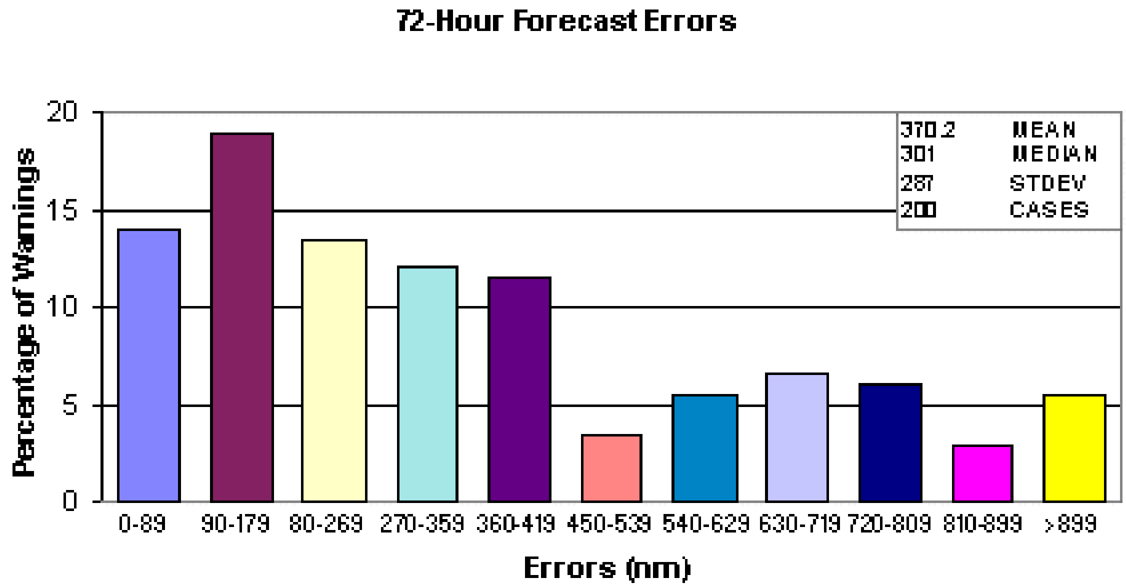


Figure 5-2f. Frequency distribution of 72-hour track forecast errors (90 nm increments) for the North West Pacific Ocean tropical cyclones in 1998.

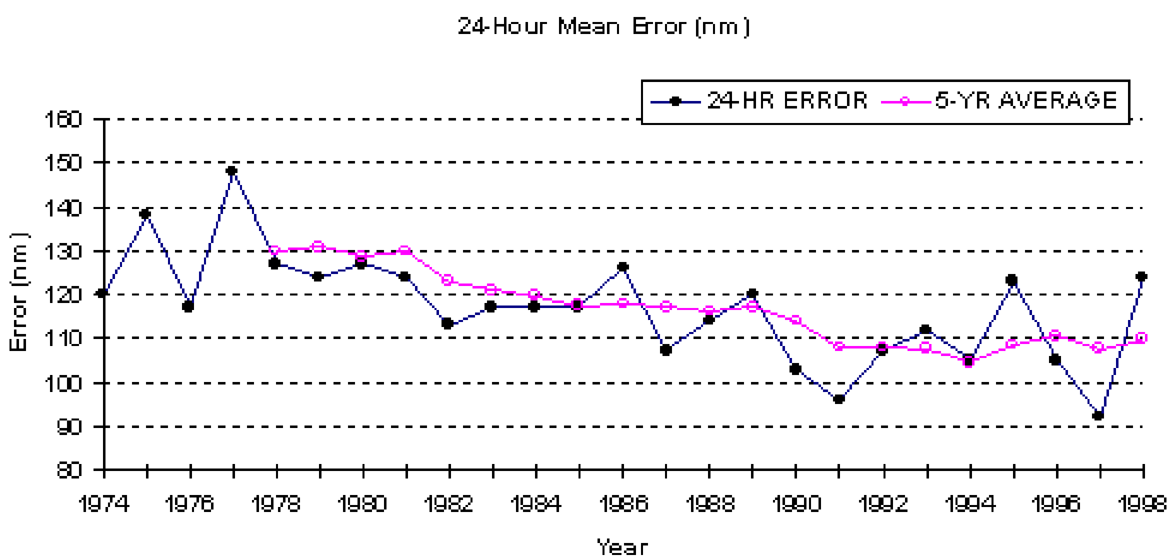


Figure 5-3a. Mean track forecast error (nm) and 5-year running mean for 24 hours for Northern Pacific Ocean tropical cyclones from 1974-1998.

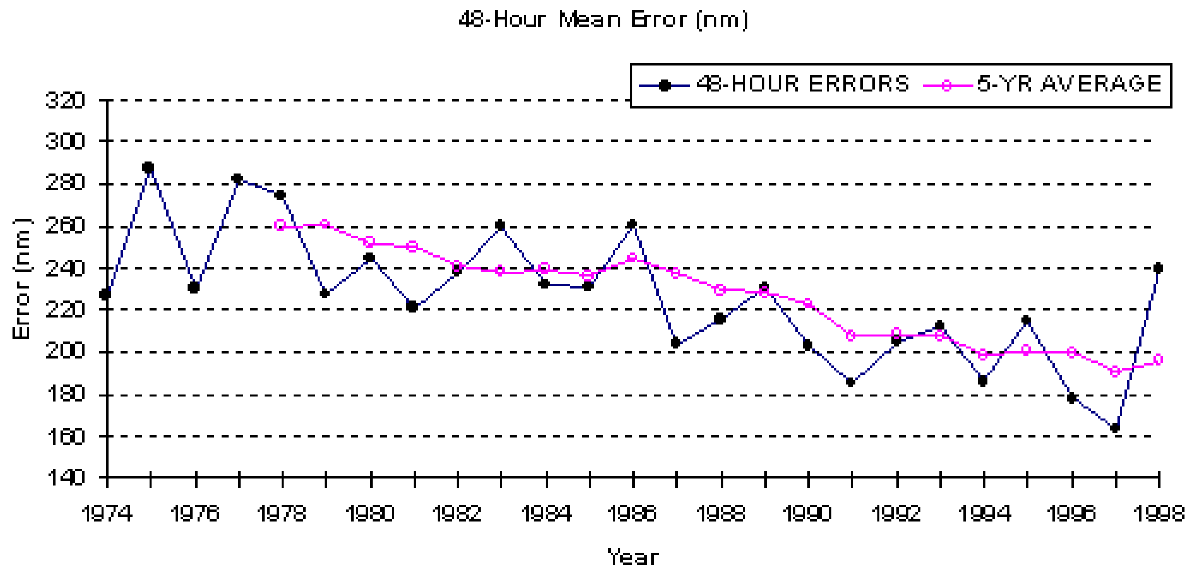


Figure 5-3b. Mean track forecast error (nm) and 5-year running mean for 48 hours for Northern Pacific Ocean tropical cyclones from 1974-1998.

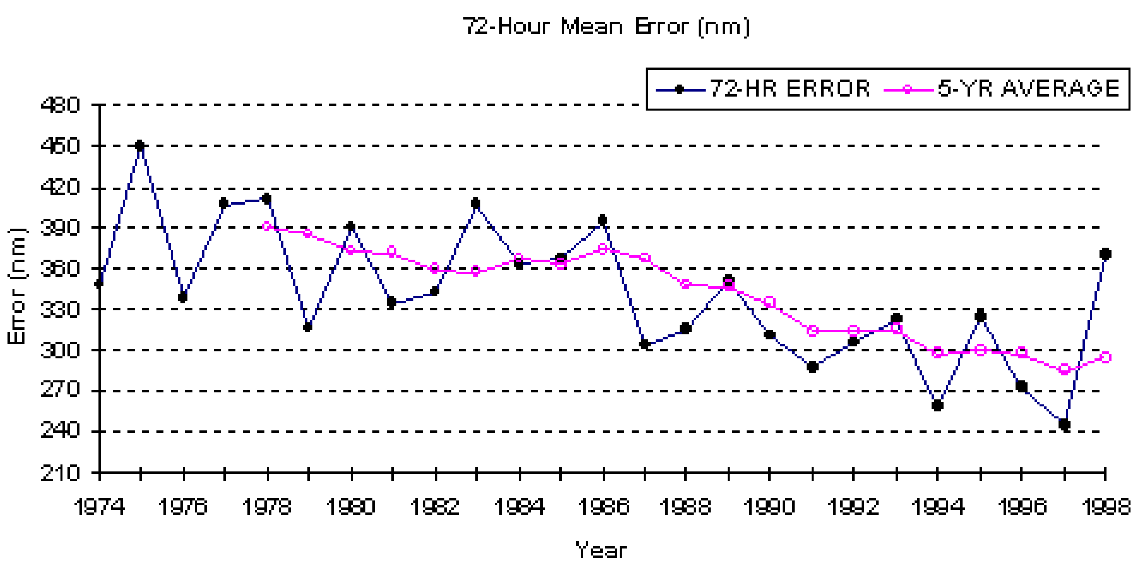


Figure 5-3c. Mean track forecast error (nm) and 5-year running mean for 72 hours for Northern Pacific Ocean tropical cyclones from 1974-1998.

Table 5-1 INITIAL POSITION AND FORECAST ERRORS (NM) FOR THE WESTERN NORTH PACIFIC 1984-1998

	Initial Position		24-Hour				48-Hour				72-Hour			
	Number	Error	Number	Track	Along	Cross	Number	Track	Along	Cross	Number	Track	Along	Cross
1984	611	22	492	117	84	64	378	232	163	131	286	363	238	216
1985	592	18	477	117	80	68	336	231	153	138	241	367	230	227
1986	743	21	645	126	85	70	535	261	183	151	412	394	276	227
1987	657	18	563	107	71	64	465	204	134	127	389	303	198	186
1988	465	23	373	114	85	58	262	216	170	103	183	315	244	159
1989	710	20	625	120	83	69	481	231	162	127	363	350	265	177
1990	794	21	658	103	72	60	525	203	148	110	432	310	225	168
1991	835	22	733	96	69	53	599	185	137	97	484	287	229	146
1992	941	25	841	107	77	59	687	205	143	116	568	305	210	172
1993	853	26	725	112	79	63	570	212	151	117	437	321	226	173
1994	1058	24	932	98	85	62	753	176	158	105	608	242	218	144
1995	559	29	539	123	89	67	421	215	159	117	319	325	240	167
1996	922	25	880	105	76	56	711	178	134	89	607	272	203	137
1997	910	20	865	93	76	55	752	164	134	87	642	245	202	120
1998	450	22	375	124	98	58	273	239	178	127	202	370	274	201
15Yr														
Avg	740	22	648	111	81	62	517	210	154	116	412	318	232	175

Table 5-2 MEAN FORECAST TRACK ERRORS (NM) FOR WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959-1998

	24-HOUR				48-HOUR				72-HOUR			
YEAR (Notes)	TY (1)	TC (3)	CRS TRK (2)	ALNG TRK (2)	TY (1)	TC (3)	CRS TRK (2)	ALNG TRK (2)	TY (1)	TC (3)	CRS TRK (2)	ALNG TRK (2)
1959	117*				267*							
1960	177*				354*							
1961	136				274							
1962	144				287				476			
1963	127				246				374			
1964	133				284				429			
1965	151				303				418			
1966	136				280				432			
1967	125				276				414			
1968	105				229				337			
1969	111				237				349			
1970	98	104			181	190			272	279		
1971	99	111	64		203	212	118		308	317	177	
1972	116	117	72		245	245	146		382	381	210	
1973	102	108	74		193	197	134		245	253	162	
1974	114	120	78		218	226	157		357	348	245	
1975	129	138	84		279	288	181		442	450	290	
1976	117	117	71		232	230	132		336	338	202	
1977	140	148	83		266	283	157		390	407	228	
1978	120	127	71	87	241	271	151	194	459	410	218	296
1979	113	124	76	81	219	226	138	146	319	316	182	214

1. Forecasts were verified for typhoons when intensities were at least 35kt at warning times

2. Cross-track and along-track errors were adopted by the JTWC in 1986. Right angle errors (used prior to 1986) were recomputed as cross-track errors after-the fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track.

3. Mean forecast errors for all warned systems in Northwest Pacific.

*Forecast positions north of 35 degrees North latitude were not verified.

**1994 statistics were recalculated to resolve earlier Along and Cross-Track discrepancies.

Table 5-2 MEAN FORECAST TRACK ERRORS (NM) FOR WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959-1998 (continued)

	24-HOUR				48-HOUR				72-HOUR			
YEAR (Notes)	TY (1)	TC (3)	CRS TRK (2)	ALNG TRK (2)	TY (1)	TC (3)	CRS TRK (2)	ALNG TRK (2)	TY (1)	TC (3)	CRS TRK (2)	ALNG TRK (2)
1980	116	126	76	86	221	243	147	165	362	389	230	266
1981	117	124	77	80	215	221	131	146	342	334	219	206
1982	114	113	70	74	229	238	142	162	337	342	211	223
1983	110	117	73	76	247	260	164	169	384	407	263	259
1984	110	117	64	84	228	232	131	163	361	363	216	238
1985	112	117	68	80	228	231	138	153	355	367	227	230
1986	117	126	70	85	261	261	151	183	403	394	227	276
1987	101	107	64	71	211	204	127	134	318	303	186	198
1988	107	114	58	85	222	216	103	170	327	315	159	244
1989	107	120	69	83	214	231	127	162	325	350	177	265
1990	98	103	60	72	191	203	110	148	299	310	168	225
1991	93	96	53	69	187	185	97	137	298	287	146	229
1992	97	107	59	77	194	205	116	143	295	305	172	210
1993	102	112	63	79	205	212	117	151	320	321	173	226
1994**	96	105	56	76	172	186	105	131	244	258	152	176
1995	105	123	67	89	200	215	117	159	311	325	167	240
1996	85	105	56	76	157	178	89	134	252	272	137	203
1997	86	93	55	76	159	164	87	134	251	245	120	202
1998	127	124	58	98	263	239	127	178	392	370	201	274
Averages	108	108	63	73	217	209	121	141	331	314	182	213

1. Forecasts were verified for typhoons when intensities were at least 35kt at warning times

2. Cross-track and along-track errors were adopted by the JTWC in 1986. Right angle errors (used prior to 1986) were recomputed as cross-track errors after-the fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track.

3. Mean forecast errors for all warned systems in Northwest Pacific.

*Forecast positions north of 35 degrees North latitude were not verified.

**1994 statistics were recalculated to resolve earlier Along and Cross-Track discrepancies.

5.1.2 NORTH INDIAN OCEAN

The frequency distributions of errors for warning positions and 12-, 24-, 36-, 48- and 72-hour forecasts are presented in Figures 5-4a through 5-4f. Table 5-3 includes mean track, along-track and cross-track errors for 1984-1998. Figure 5-5 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours since 1981.

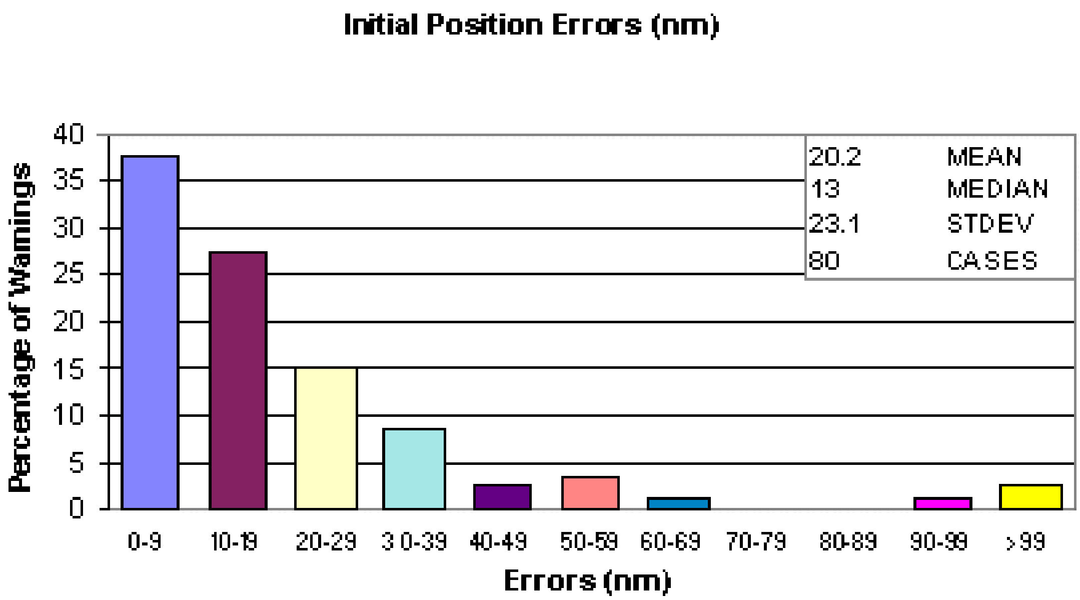


Figure 5-4a. Frequency distribution of initial warning position errors (10 nm increments) for the North Indian Ocean tropical cyclones in 1998.

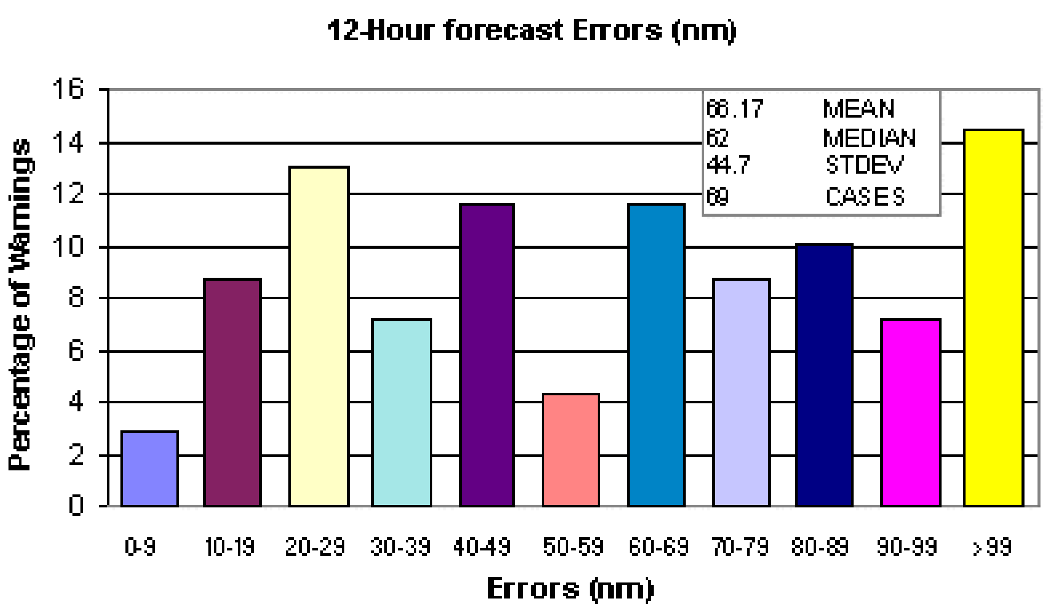


Figure 5-4b. Frequency distribution of 12-hour track forecast errors (10 nm increments) for the North Indian Ocean tropical cyclones in 1998.

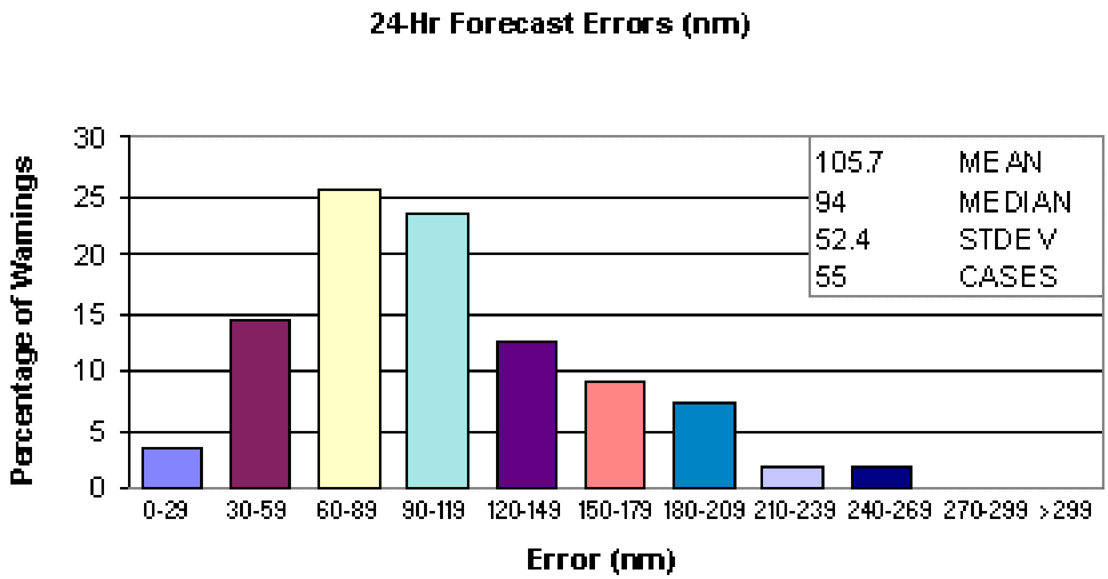


Figure 5-4c. Frequency distribution of 24-hour track forecast errors (30 nm increments) for the North Indian Ocean tropical cyclones in 1998.

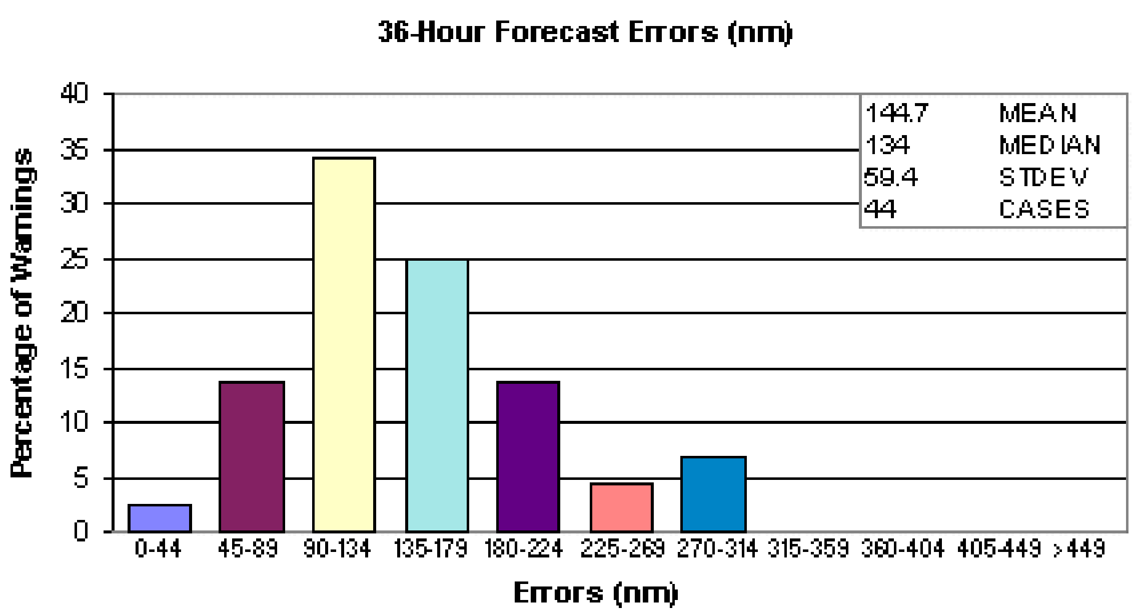


Figure 5-4d. Frequency distribution of 36-hour track forecast errors (45 nm increments) for the North Indian Ocean tropical cyclones in 1998.

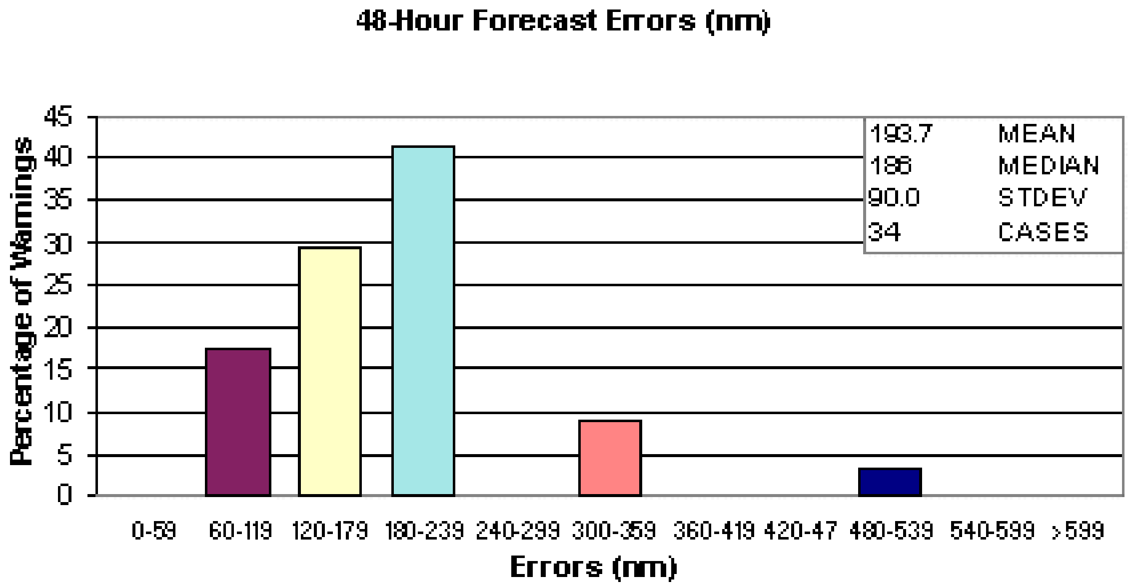


Figure 5-4e. Frequency distribution of 48-hour track forecast errors (60 nm increments) for the North Indian Ocean tropical cyclones in 1998.

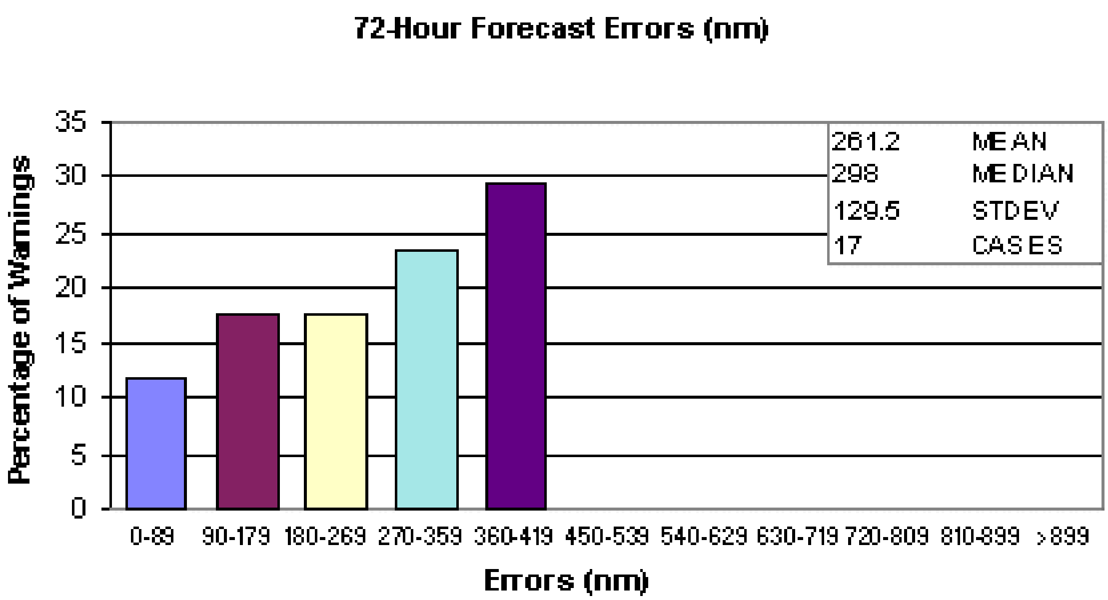


Figure 5-4f. Frequency distribution of 72-hour track forecast errors (90 nm increments) for the North Indian Ocean tropical cyclones in 1998.

Table 5-3 JTWC INITIAL POSITION AND FORECAST ERRORS (NM) FOR THE NORTHERN INDIAN OCEAN 1984-1998

	Initial Position		24-Hour				48-Hour				72-Hour			
	Number	Error	Number	Track	Along	Cross	Number	Track	Along	Cross	Number	Track	Along	Cross
1985	53	31	30	122	102	53	8	242	119	194	0			
1986	28	52	16	134	118	53	7	168	131	80	5	269	189	180
1987	83	42	54	144	97	100	25	205	125	140	21	305	219	188
1988	44	34	30	120	89	63	18	219	112	176	12	409	227	303
1989	44	19	33	88	62	50	17	146	94	86	12	216	164	11
1990	46	31	36	101	85	43	24	146	117	67	17	185	130	104
1991	56	38	43	129	107	54	27	235	200	89	14	450	356	178
1992	191	35	149	128	73	86	100	244	141	166	62	398	276	218
1993	36	27	28	125	87	79	20	198	171	74	12	231	176	116
1994	60	25	44	97	80	44	28	153	124	63	13	213	177	92
1995	54	30	47	138	119	58	32	262	247	77	20	342	304	109
1996	135	33	123	134	94	80	85	238	181	127	58	311	172	237
1997	56	29	42	119	87	49	29	201	168	92	17	228	195	110
1998	80	20	55	106	84	51	34	198	135	106	17	262	188	144
15-Yr Avg	69	32	51	123	94	62	32	209	152	112	21*	273*	198*	142*

*14 year average (1985 not available)

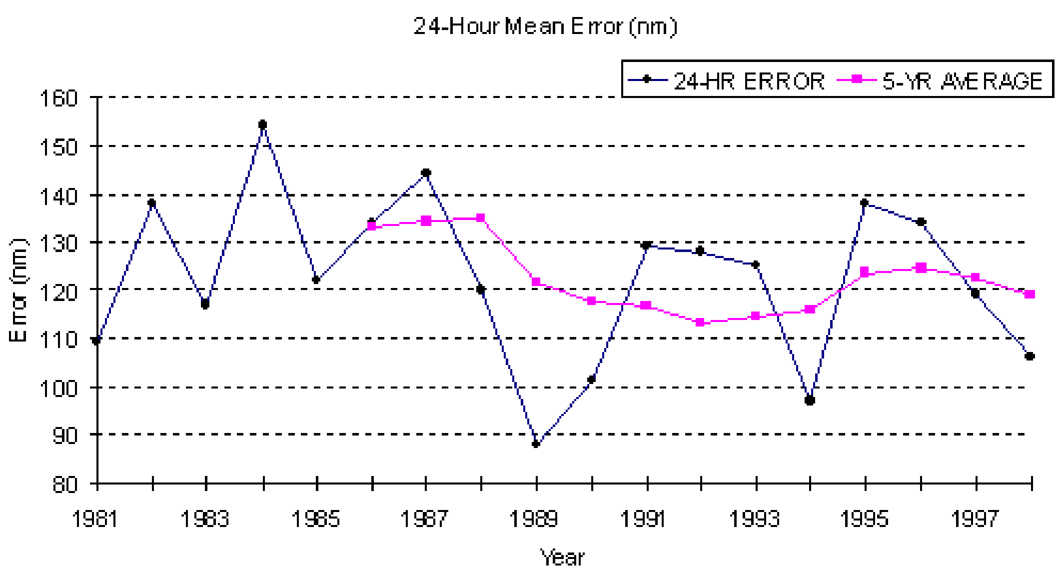


Figure 5-5a. Mean track forecast error (nm) and 5-year running mean for 24 hours for Northern Indian Ocean tropical cyclones from 1981-1998.

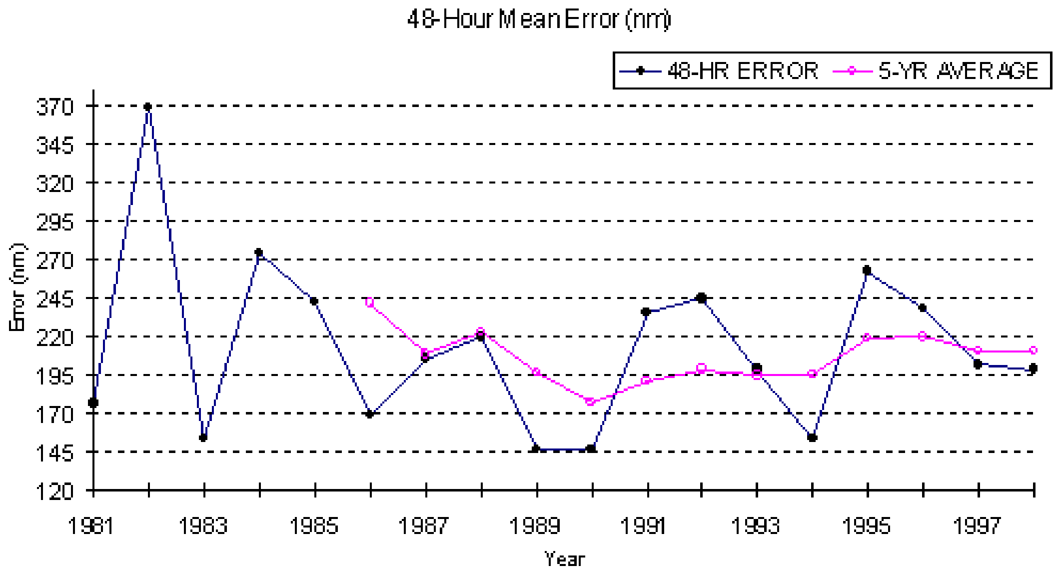


Figure 5-5b. Mean track forecast error (nm) and 5-year running mean for 48 hours, for Northern Indian Ocean tropical cyclones from 1981-1998.

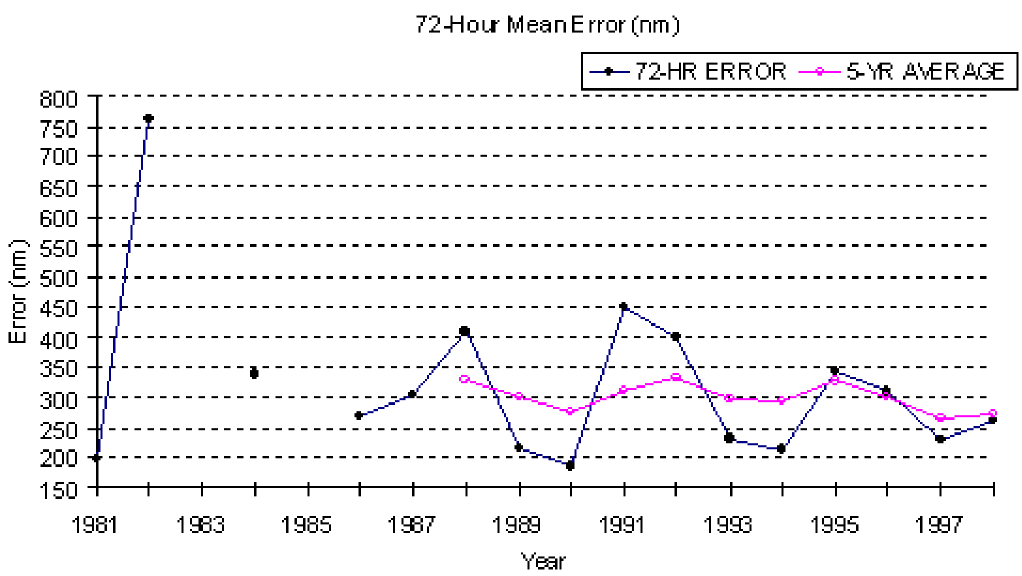


Figure 5-5c. Mean track forecast error (nm) and 5-year running mean for 72 hours for Northern Indian Ocean tropical cyclones from 1981-1998. The data breaks in the chart are due to no 72 hour forecasts during the year.

5.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS

The frequency distributions of errors for warning positions and 12-, 24-, 36-,48- and 72-hour forecasts are presented in Figures 5-6a through 5-6f. Table 5-4 includes mean track, along-track and cross-track errors for 1984-1998. Figure 5-7 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours from 1981-1998.

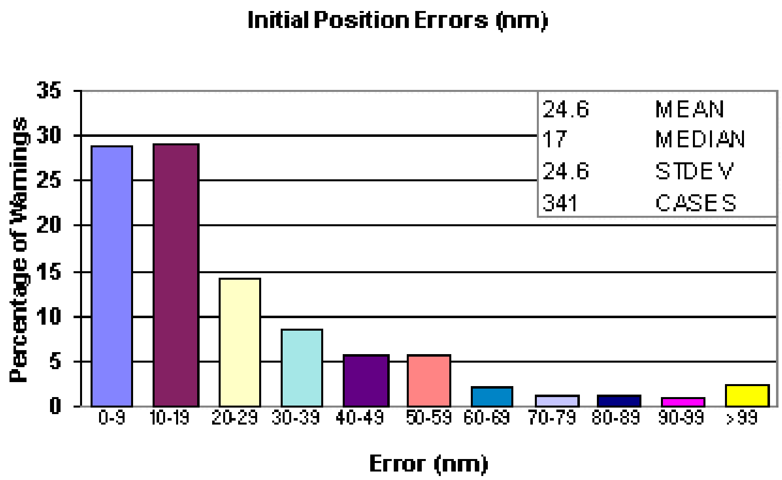


Figure 5-6a. Frequency distribution of initial warning position errors (10 nm increments) for Southwest Pacific and South Indian Ocean tropical cyclones in 1998.

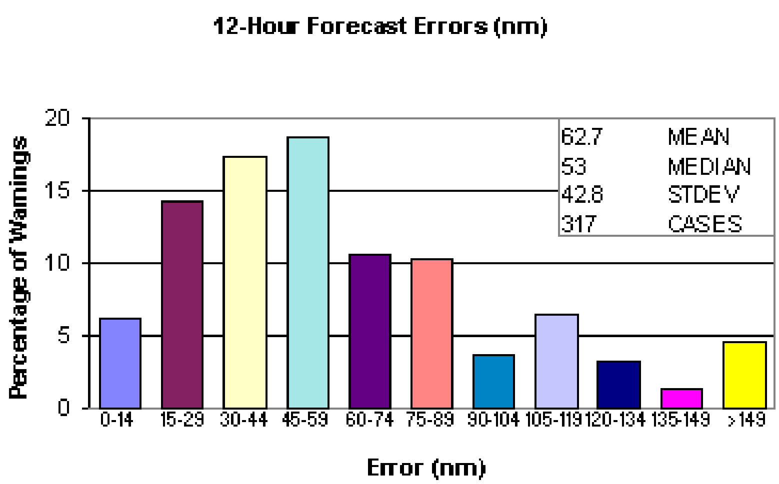


Figure 5-6b. Frequency distribution of 12-hour forecast errors (15 nm increments) for Southwest Pacific and South Indian Ocean tropical cyclones in 1998.

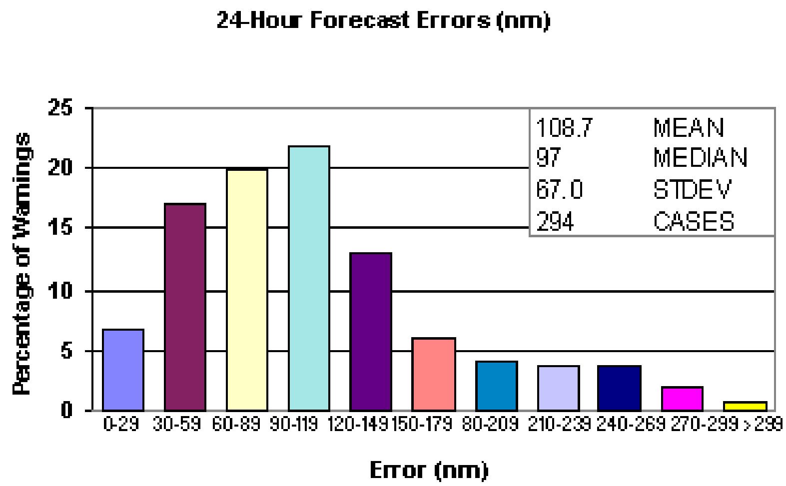


Figure 5-6c. Frequency distribution of 24-hour forecast errors (30 nm increments) for Southwest Pacific and South Indian Ocean tropical cyclones in 1998.

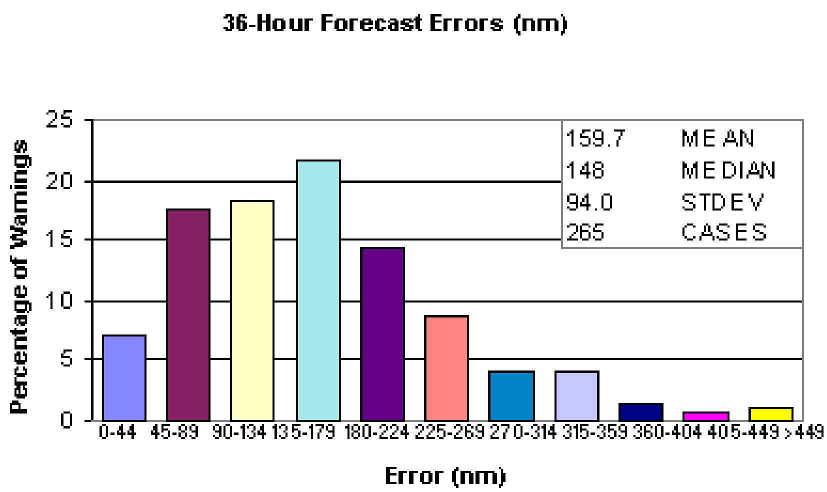


Figure 5-6d. Frequency distribution of 36-hour forecast errors (45 nm increments) for Southwest Pacific and South Indian Ocean tropical cyclones in 1998.

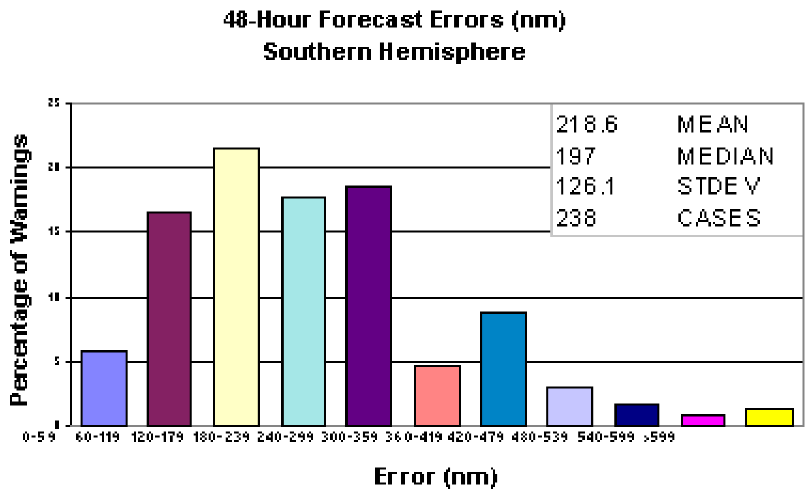


Figure 5-6e. Frequency distribution of 48-hour forecast errors (60 nm increments) for Southwest Pacific and South Indian Ocean tropical cyclones in 1998.

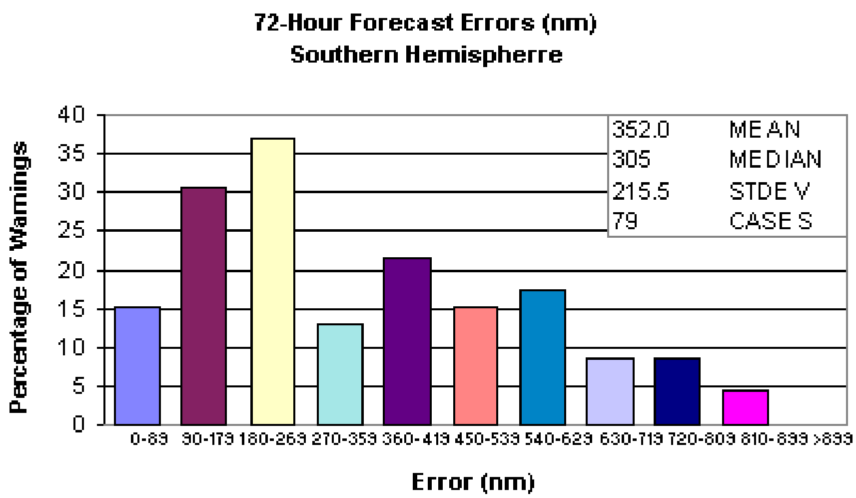


Figure 5-6f. Frequency distribution of 72-hour forecast errors (90 nm increments) for Southwest Pacific and South Indian Ocean tropical cyclones in 1998.

Table 5-4 JTWC INITIAL POSITION AND FORECAST ERRORS (NM) FOR THE SOUTHERN HEMISPHERE 1984-1998

	Initial Position		24-Hour				48-Hour				72-Hour			
	Number	Error	Number	Track	Along	Cross	Number	Track	Along	Cross	Number	Track	Along	Cross
1984	301	36	252	133	90	79	191	231	159	134				
1985	306	36	257	134	92	79	193	236	169	132				
1986	279	40	227	129	86	77	171	262	169	164				
1987	189	46	138	145	94	90	101	280	153	138				
1988	204	34	99	146	98	83	48	290	246	144				
1989	287	31	242	124	84	73	186	240	166	136				
1990	272	27	228	143	105	74	177	263	178	152				
1991	264	24	231	115	75	69	185	220	152	129				
1992	267	28	230	124	91	64	208	240	177	129				
1993	257	21	225	102	74	57	176	199	142	114				
1994	386	28	345	115	77	68	282	224	147	134				
1995	245	24	222	108	82	55	175	198	144	108	53	291	169	190
1996	343	24	298	125	90	67	237	240	174	129	46	277	221	133
1997	561	24	499	109	82	72	442	210	163	135	150	288	248	175
1998	329	26	305	111	85	52	245	219	169	108	81	349	261	171
15Yr														
Avg	299	30	253	124	87	71	201	237	167	132	83*	301*	224*	167*

*4-year average

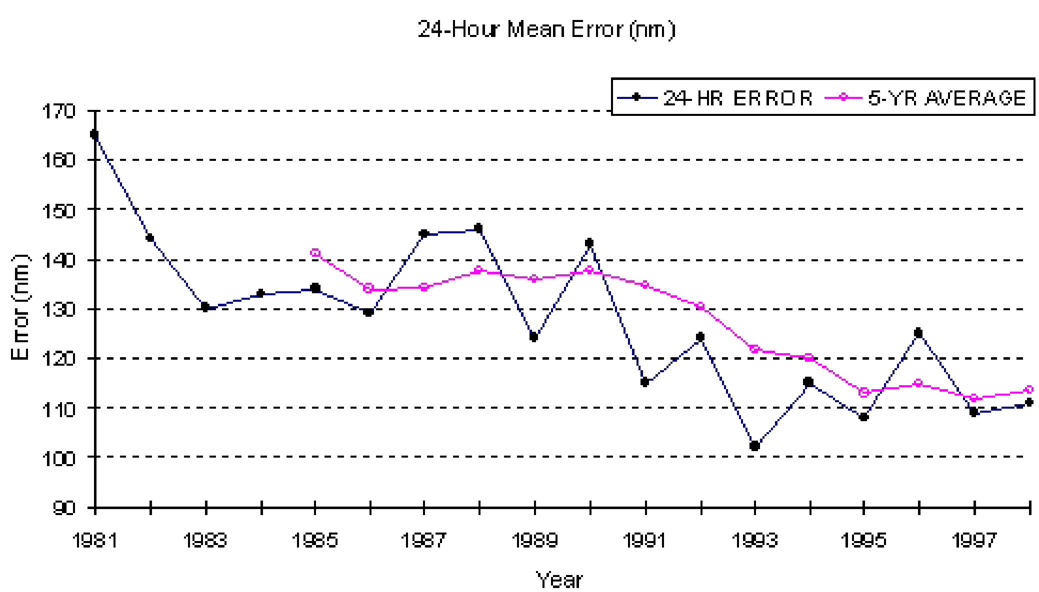


Figure 5-7a. Mean track forecast error (nm) and 5-year running mean for 24 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1981-1998.

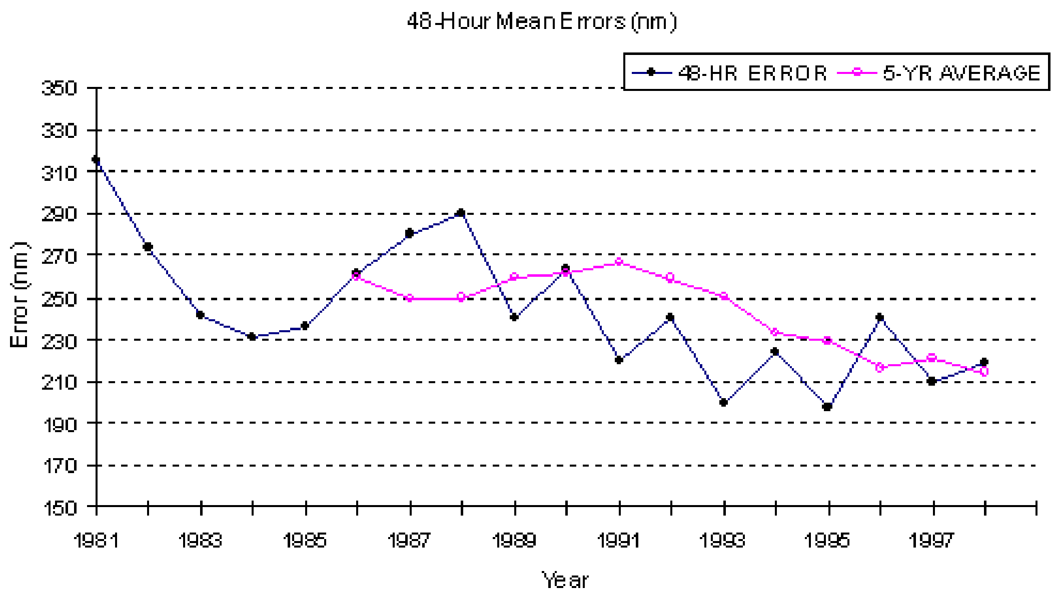


Figure 5-7b. Mean track forecast error (nm) and 5-year running mean for 48 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1981-1998.

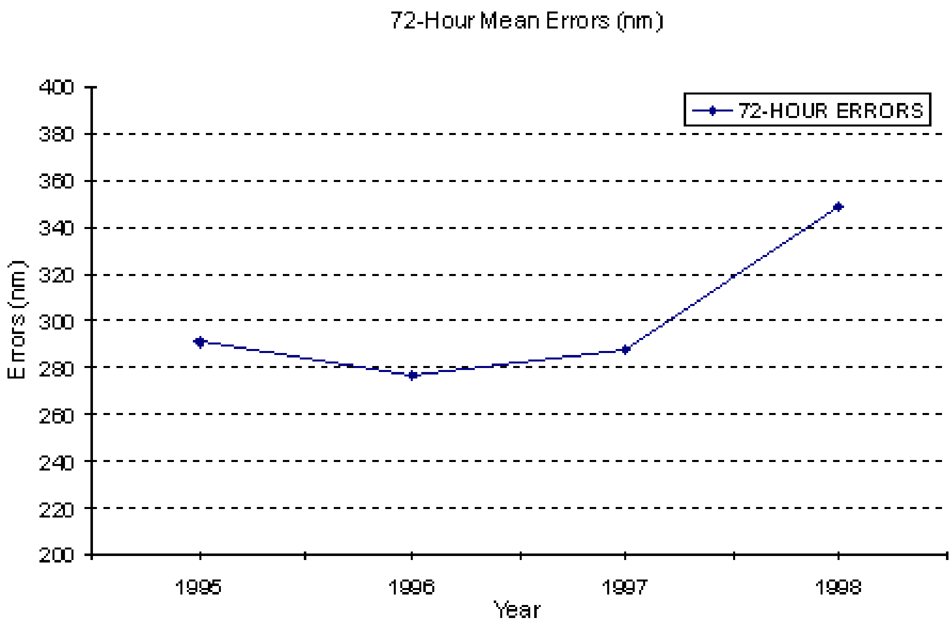


Figure 5-7c. Mean track forecast error (nm) and 5-year running mean for 72 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1981-1998. The 72-hour chart was added this year.

5.2 COMPARISON OF OBJECTIVE AIDS

JTWC uses a variety of objective aids for guidance in the warning preparation process. Multiple aids are required, because each aid has particular strengths and weaknesses which vary by basin, numerical model initialization, time of year, synoptic situation and forecast period. The accuracy of objective aid forecasts depends on both the specified position and the past motion of the tropical cyclone as determined by the working best track. JTWC initializes its objective aids using an extrapolated working best track position, called a "bogus", so the output of the aid will start at the valid time of the next warning initial position.

Unless stated otherwise, all of the objective aids discussed below run in all basins covered by JTWC's AOR and routinely provide forecast positions at 12-, 24-, 36-, 48-, and 72-hours. The aids can be divided into five general categories: extrapolation, climatology and analogs, statistical, dynamic, and hybrids.

5.2.1 EXTRAPOLATION (XTRP)

Past speed and direction are computed using the rhumb line distance between the current and 12-hour old positions of the tropical cyclone. Extrapolation from the current warning position is used to compute forecast positions.

5.2.2 CLIMATOLOGY and ANALOGS

5.2.2.1 CLIMATOLOGY (CLIM)

Employs time and location windows relative to the current position of the tropical cyclone to determine which historical storms will be used to compute the forecast. The historical database is from 1945-1981 for the Northwest Pacific, and from 1900 to 1990 for the rest of JTWC's AOR. Objective intensity forecasts are available from these databases. Scatter diagrams of expected tropical cyclone motion at bifurcation points are also available from these databases.

5.2.2.2 ANALOG

A revised Typhoon Analog 1993 (TYAN93) picks the top matches with the basin climatology of historical tropical cyclone best tracks. Matches are based upon the differences between the direction and speed of the superimposed historical best track positions and the past direction and speed of the cyclone. Specifically, the directions and speeds are calculated from the 12-hour old position to the current ”fix” position and the 24-hr old position to the ”fix” position. Separate comparisons are made for climatology cyclone tracks classified as ”straight,” ”recurver” and ”other”. There is also a ”total” group, that includes the top matches without regard to classification of tracks.

TYAN93 works in the same manner for all basins. The time-window is +/- 35 days from the ”fix.” The space-window is +/- 2.5 degrees latitude and +/- 5 degrees longitude from the ”fix” position on the first pass of each forecast. The maximum-wind-speed window is as follows (for basins with climatology wind speeds):

a. If ”fix” wind speed is ¡ 25 kt, (13 m/s) climatology cyclone wind speed must be ¡ 30 kt. (15 m/s)

b. If ”fix” wind speed is 30 kt, (15 m/s) climatology cyclone wind speed must be in range from 25 to 35 kt. (13 to 17 m/s)

c. If ”fix” wind speed is ¿ 35 kt (17 m/s), climatology cyclone wind speed must be at least 35 kt. (17 m/s).

Matching is based upon weighted direction and speed errors. Forecasting is based upon ”straight” and ”recurver” type climatology tropical cyclones, where the 12-hour and 24-hour best ”straight” (”recurver”) matches are combined into one set of best matches for ”straight” (”recurver”).

5.2.3 STATISTICAL

5.2.3.1 CLIMATOLOGY AND PERSISTENCE (CLIPER or CLIP)

A statistical regression technique based on climatology, current position and 12-hour and 24-hour past movement. This technique is the baseline against which forecast skill is measured. CLIP in the western North Pacific uses third-order regression equations, and is based on the work of Xu and Neumann (1985). CLIPER has been available outside this basin since mid-1990, with regression coefficients recently recomputed by FNMOC based on the updated 1900-1989 database.

5.2.3.2 COLORADO STATE UNIVERSITY MODEL (CSUM)

A statistical-dynamical technique based on the work of Matsumoto (1984). Predictor parameters include the current and 24-hr old position of the storm, heights from the current and 24-hr old NOGAPS 500-mb analyses, and heights from the 24-hr and 48-hr NOGAPS 500-mb prognoses. Height values from 200-mb fields are substituted for storms that have an intensity exceeding 90 kt and are located north of the subtropical ridge. Three distinct sets of regression equations are used depending on whether the storm's direction of motion falls into "below", "on", or "above" the subtropical ridge categories. During the development of the regression equation coefficients for CSUM, the so-called "perfect prog" approach was used, in which verifying analyses were substituted for the numerical prognoses that are used when CSUM is run operationally. Thus, CSUM was not "tuned" to any particular version of NOGAPS, and in fact, the performance of CSUM should presumably improve as new versions of NOGAPS improve. CSUM runs only in the western North Pacific, South China Sea, and North Indian Ocean basins.

5.2.3.3 JTWC92 or JT92

JTWC92 is a statistical-dynamical model for the North West Pacific Ocean basin which forecasts tropical cyclone positions at 12-hour intervals to 72 hours. The model uses the deep-layer mean height field derived from the NOGAPS forecast fields. These deep-layer mean height fields are spectrally truncated to wave numbers 0 through 18 prior to use in JTWC92. Separate forecasts are made for each position. That is, the forecast 24-hour position is not a 12-hour forecast from the forecasted 12-hour position.

JTWC92 uses five internal sub-models which are blended and iterated to produce the final forecasts. The first sub-model is a statistical blend of climatology and persistence, known as CLIPER. The second sub-model is an analysis mode predictor, which only uses the "analysis" field. The third sub-model is the forecast mode predictor, which uses only the forecast fields. The fourth sub-model is a combination of 1 and 2 to produce a "first estimate" of the 12-hourly forecast positions. The fifth sub-model uses the output of the "first estimate" combined with 1, 2, and 3 to produce the forecasts. The iteration is accomplished by using the output of sub-model 5 as though it were the output from sub-model 4. The optimum number of iterations has been determined to be three.

When JTWC92 is used in the operational mode, all the NOGAPS fields are forecast fields. The 00Z and 12Z tropical forecasts are based upon the previous 12-hour old synoptic time NOGAPS forecasts. The 06Z and 18Z tropical forecasts are based on the previous 00Z and 12Z NOGAPS forecasts, respectively. Therefore, operationally, the second sub-model uses forecast fields and not analysis fields.

5.2.4 DYNAMIC

5.2.4.1 NOGAPS VORTEX TRACKING ROUTINE (NGPS/X)

Tropical cyclone vortices are tracked in NOGAPS by converting the 1000-mb u and v wind component fields into isogons. The intersection of isogons are either the center of a cyclonic or anticyclonic circulation, or a col. The tracking program starts at the last known location of the cyclone - a warning position. Based on this position and the last known speed and direction of movement, the program hunts for the next cyclonic center representing the tropical cyclone. Confidence factors are generated within the program and are modified, as required, by a quality control program that formats the data for transmission.

5.2.4.2 GEOPHYSICAL FLUID DYNAMICS MODEL - NAVY (GFDN)

This model is an adaptation of the Geophysical Fluid Dynamics Model used by the National Center for Environmental Prediction (NCEP). This model uses a triple-nested movable mesh with 18 sigma levels. The outer mesh domain covers a 75 degrees x 75 degrees area with a horizontal resolution of 1 degree and is fixed for the duration of the model run based on the initial location and movement of the tropical cyclone. The 10 degrees x 10 degrees middle and a 5 degrees x 5 degrees inner (resolution 1/6 degrees) nested meshes move with the cyclone. Based on the global analysis and an initialization message, the TC is removed from the global analysis, and replaced by a synthetic vortex which has an asymmetric (beta-advection) component added. Boundary conditions are updated periodically from forecast fields generated by a global forecast model. In addition to standard output fields, the model outputs TC track forecasts and maximum isotach swaths indicating the location of maximum winds in relation to the TC track.

5.2.4.3 FNMOC BETA AND ADVECTION MODEL (FBAM)

This model is an adaptation of the Beta and Advection model used by the National Center for Environmental Prediction (NCEP). The forecast motion results from a calculation of environmental steering and an empirical correction for the observed vector difference between that steering and the 12-hour old storm motion. The steering is computed from the NOGAPS Deep Layer Mean (DLM) wind fields which are a weighted average of the wind fields computed for the 1000-mb to 100-mb levels. The difference between past storm motion and the DLM steering is treated as if the storm were a Rossby wave with an "effective radius" propagating in response to the horizontal gradient of the coriolis parameter, beta. The forecast proceeds in one-hour steps, recomputing the effective radius as beta changes with storm latitude, and blending in a persistence bias for the first 12 hours.

5.2.5 HYBRIDS

5.2.5.1 HALF PERSISTENCE AND CLIMATOLOGY (HPAC)

Forecast positions generated by equally weighting the forecasts given by XTRP and CLIM.

5.2.5.2 DYNAMIC AVERAGE (DAVE)

A simple average of all dynamic forecast aids: NOGAPS (NGPS), Bracknell (EGRR), JMA Typhoon Model (JTYM), JT92, FBAM, and CSUM.

5.3 TESTING AND RESULTS

A comparison of selected techniques is included in Table 5-5 for all western North Pacific tropical cyclones, Table 5-6 for all North Indian Ocean tropical cyclones and Table 5-7 for the Southern Hemisphere. For example, in Table 5-5 for the 12-hour mean forecast error, 173 cases available for a homogeneous comparison, the average forecast error at 12 hours was 72 nm for NGPS and 61 nm for JTWC. The difference of 11 nm is shown in the lower right. Differences are not always exact, due to computational round-off.

Table 5-5 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		FBAM		CSUM		EGRR		GFDN		JGSM		JTYM		CLIP		DAVE		RJTD	
JTWC	420	68																				
	68	0																				
NGPS	173	61	176	73																		
	72	11	73	0																		
FBAM	412	68	175	73	438	71																
	69	1	64	-9	71	0																
CSUM	321	65	162	68	333	67	333	69														
	68	3	63	-5	69	2	69	0														
EGRR	4	32	3	44	4	41	4	60	4	144												
	144	112	163	119	144	103	144	84	144	0												
GFDN	158	68	0	0	155	68	102	70	1	87	158	72										
	72	4	0	0	72	4	71	1	106	19	72	0										
JGSM	112	61	101	63	112	63	106	69	3	163	5	73	114	63								
	62	1	59	-4	62	-1	62	-7	43	-120	95	22	63	0								
JTYM	116	65	2	63	115	66	80	69	0	0	101	66	8	81	118	62						
	61	-4	98	35	61	-5	56	-13	0	0	61	-5	58	-23	62	0						
CLIP	420	68	175	73	438	71	333	69	4	144	158	72	113	62	118	62	451	74				
	71	3	65	-8	73	2	70	1	40	-104	72	0	69	7	71	9	74	0				
DAVE	369	65	157	71	384	69	305	68	4	144	142	71	103	61	107	63	386	71	386	67		
	66	1	60	-11	67	-2	64	-4	43	-101	65	-6	58	-3	63	0	67	-4	67	0		
RJTD	9	53	5	85	9	54	4	55	0	0	3	69	2	118	2	80	9	48	7	42	9	80
	80	27	96	11	80	26	82	27	0	0	47	-22	118	0	65	-15	80	32	79	37	80	0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		FBAM		CSUM		EGRR		GFDN		JGSM		JTYM		CLIP		DAVE		RJTD	
JTWC	375	124																				
	124	0																				
NGPS	163	116	166	119																		
	118	2	119	0																		
FBAM	369	125	165	119	396	126																
	125	0	122	3	126	0																
CSUM	289	123	153	114	302	127	302	135														
	135	12	128	14	135	8	135	0														
EGRR	153	121	139	120	157	124	141	134	168	119												
	116	-5	113	-7	119	-5	109	-25	119	0												
GFDN	139	125	0	0	136	115	90	140	3	155	139	103										
	103	-22	0	0	103	-12	106	-34	100	-55	103	0										
JGSM	106	122	99	106	106	115	101	142	94	104	5	193	108	96								
	96	-26	92	-14	95	-20	95	-47	96	-8	185	-8	96	0								

Table 5-5 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC

JTYM	112	131	2	136	111	116	78	152	4	176	96	103	8	141	114	93						
	94	-37	121	-15	93	-23	87	-65	99	-77	90	-13	114	-27	93	0						
CLIP	375	124	165	119	396	126	302	135	159	118	139	103	107	96	114	93	407	138				
	134	10	129	10	136	10	133	-2	135	17	135	32	136	40	143	50	138	0				
DAVE	331	121	149	117	348	124	277	135	141	114	126	103	99	97	103	95	349	134	349	118		
	117	-4	111	-6	118	-6	118	-17	118	4	113	10	113	16	117	22	118	-16	118	0		
RJTD	210	125	100	114	209	117	173	144	99	101	94	102	90	97	92	93	211	137	195	116	212	101
	101	-24	102	-12	102	-15	103	-41	103	2	98	-4	103	6	101	8	102	-35	102	-14	101	0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		FBAM		CSUM		EGRR		GFDN		JGSM		JTYM		CLIP		DAVE		RJTD	
JTWC	322	178																				
	178	0																				
NGPS	137	175	141	168																		
	165	-10	168	0																		
FBAM	316	179	140	167	348	187																
	185	6	188	21	187	0																
CSUM	243	179	133	163	259	192	259	206														
	209	30	204	41	206	14	206	0														
EGRR	1	81	1	47	1	79	1	36	1	252												
	252	171	252	205	252	173	252	216	252	0												
GFDN	118	173	0	0	116	173	73	219	0	0	119	136										
	136	-37	0	0	134	-39	134	-85	0	0	136	0										
JGSM	98	188	92	158	99	185	95	234	1	252	4	180	100	131								
	132	-56	130	-28	130	-55	130	-104	70	-182	174	-6	131	0								
JTYM	101	190	2	191	100	178	69	238	0	0	85	140	7	148	103	137						
	139	-51	159	-32	137	-41	132	-106	0	0	131	-9	119	-29	137	0						
CLIP	322	178	140	167	348	187	259	206	1	252	119	136	100	131	103	137	359	205				
	202	24	201	34	203	16	201	-5	76	-176	208	72	216	85	220	83	205	0				
DAVE	285	178	128	168	307	184	238	208	1	252	109	135	93	132	93	141	308	205	308	172		
	172	-6	172	4	172	-12	173	-35	76	-176	168	33	181	49	178	37	172	-33	172	0		
RJTD	6	128	2	144	6	187	3	185	0	0	2	116	1	59	1	68	6	157	5	167	6	105
	105	-23	86	-58	105	-82	109	-76	0	0	80	-36	59	0	68	0	105	-52	108	-59	105	0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		FBAM		CSUM		EGRR		GFDN		JGSM		JTYM		CLIP		DAVE		RJTD	
JTWC	273	239																				
	239	0																				
NGPS	118	230	122	219																		
	218	-12	219	0																		
FBAM	268	241	121	217	305	258																
	260	19	252	35	258	0																
CSUM	208	243	115	215	228	267	228	288														

Table 5-5 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC

	295	52	290	75	288	21	288	0														
EGRR	114	237	99	229	118	260	109	301	128	200												
	197	-40	192	-37	199	-61	198	-103	200	0												
GFDN	104	231	0	0	105	244	63	294	3	174	108	180										
	183	-48	0	0	178	-66	170	-124	187	13	180	0										
JGSM	92	258	81	210	92	267	89	335	81	197	4	217	93	178								
	180	-78	178	-32	175	-92	176	-159	174	-23	238	21	178	0								
JTYM	90	258	1	252	90	251	59	331	3	202	77	187	6	198	93	178						
	180	-78	223	-29	179	-72	170	-161	293	91	173	-14	157	-41	178	0						
CLIP	273	239	121	217	305	258	228	288	120	198	108	180	93	178	93	178	315	278				
	277	38	271	54	276	18	274	-14	270	72	279	99	294	116	296	118	278	0				
DAVE	244	245	109	219	270	254	210	293	107	198	99	180	87	179	84	184	270	279	270	233		
	237	-8	235	16	233	-21	238	-55	246	48	226	46	257	78	242	58	233	-46	233	0		
RJTD	145	254	67	230	144	268	115	351	66	202	67	188	67	182	67	172	146	295	137	267	146	199
	201	-53	203	-27	199	-69	192	-159	217	15	185	-3	205	23	191	19	199	-96	203	-64	199	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		FBAM		CSUM		EGRR		GFDN		JGSM		JTYM		CLIP		DAVE		RJTD	
JTWC	202	370																				
	370	0																				
NGPS	76	361	80	334																		
	332	-29	334	0																		
FBAM	198	369	79	331	225	418																
	435	66	380	49	418	0																
CSUM	150	370	75	334	164	426	164	512														
	541	171	483	149	512	86	512	0														
EGRR	82	398	64	345	84	446	79	585	93	349												
	350	-48	326	-19	359	-87	355	-230	349	0												
GFDN	76	359	0	0	76	427	44	510	0	0	78	322										
	329	-30	0	0	319	-108	298	-212	0	0	322	0										
JGSM	68	395	50	343	68	461	66	608	60	356	4	444	69	264								
	267	-128	244	-99	251	-210	250	-358	236	-120	465	21	264	0								
JTYM	67	401	1	761	66	458	43	607	1	821	56	336	6	413	68	270						
	270	-131	644	-117	271	-187	269	-338	644	-177	254	-82	275	-138	270	0						
CLIP	202	370	79	331	225	418	164	512	86	358	78	322	69	264	68	270	232	414				
	420	50	422	91	411	-7	406	-106	424	66	432	110	430	166	449	179	414	0				
DAVE	184	379	73	340	203	419	156	525	79	356	73	322	65	256	65	274	203	419	203	393		
	408	29	375	35	393	-26	395	-130	444	88	398	76	437	181	431	157	393	-26	393	0		
RJTD	106	388	40	356	105	489	85	650	51	396	48	351	49	264	47	261	107	415	101	462	107	303
	305	-83	309	-47	296	-193	296	-354	298	-98	292	-59	310	46	301	40	303	-112	302	-160	303	0

Table 5-6 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1998 - 31 DECEMBER 1998)

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		GFDN		OTCM		CLIP		HPAC	
JTWC	69	67										
	67	0										
NGPS	36	67	37	89								
	88	21	89	0								
GFDN	26	61	0	0	34	68						
	66	5	0	0	68	0						
OTCM	17	48	6	69	11	64	18	97				
	99	51	95	26	101	37	97	0				
CLIP	69	67	36	88	28	69	17	99	82	79		
	71	4	71	-17	64	-5	43	-56	79	0		
HPAC	69	67	36	88	28	69	17	99	82	79	82	78
	70	3	71	-17	61	-8	45	-54	78	-1	78	0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		OTCM		CLIP		HPAC	
JTWC	55	106												
	106	0												
NGPS	28	103	30	122										
	119	16	122	0										
EGRR	1	235	0	0	3	643								
	852	617	0	0	643	0								
GFDN	20	102	0	0	1	852	25	121						
	97	-5	0	0	133	-719	121	0						
OTCM	9	103	3	155	0	0	5	115	9	202				
	202	99	224	69	0	0	201	86	202	0				
CLIP	55	106	29	119	2	444	22	118	9	202	69	132		
	126	20	122	3	131	-313	124	6	103	-99	132	0		
HPAC	55	106	29	119	2	444	22	118	9	202	69	132	69	126
	118	12	113	-6	142	-302	115	-3	101	-101	126	-6	126	0

Table 5-6 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1998 - 31 DECEMBER 1998)

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		GFDN		OTCM		CLIP		HPAC	
JTWC	44	145										
	145	0										
NGPS	21	151	23	178								
	174	23	178	0								
GFDN	16	143	0	0	18	183						
	147	4	0	0	183	0						
OTCM	3	118	0	0	2	218	3	217				
	217	99	0	0	244	26	217	0				
CLIP	44	145	22	176	17	170	3	217	57	194		
	194	49	192	16	206	36	152	-65	194	0		
HPAC	44	145	22	176	17	170	3	217	57	194	57	180
	174	29	173	-3	188	18	124	-93	180	-14	180	0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		OTCM		CLIP		HPAC	
JTWC	34	194												
	194	0												
NGPS	16	212	18	202										
	198	-14	202	0										
EGRR	1	324	0	0	3	716								
	971	647	0	0	716	0								
GFDN	13	184	0	0	1	971	14	234						
	199	15	0	0	468	-503	234	0						
OTCM	2	186	0	0	0	0	1	159	2	381				
	381	195	0	0	0	0	597	438	381	0				
CLIP	34	194	17	202	2	515	13	199	2	381	46	262		
	276	82	283	81	148	-367	280	81	317	-64	262	0		
HPAC	34	194	17	202	2	515	13	199	2	381	46	262	46	241
	246	52	250	48	262	-253	253	54	242	-139	241	-21	241	0

Table 5-6 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1998 - 31 DECEMBER 1998)

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP		HPAC	
JTWC	17	262										
	262	0										
NGPS	8	275	10	234								
	220	-55	234	0								
EGRR	0	0	0	0	2	567						
	0	0	0	0	567	0						
GFDN	8	261	0	0	0	0	8	251				
	251	-10	0	0	0	0	251	0				
CLIP	17	262	10	234	1	123	8	251	28	359		
	415	153	392	158	42	-81	432	181	359	0		
HPAC	17	262	10	234	1	123	8	251	28	359	28	311
	323	61	323	89	184	61	328	77	311	-48	311	0

Table 5-7 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMPISPHERE (1 JUL 1997 - 30 JUNE 1998)

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		OTCM		CLIP		HPAC	
JTWC	329	64												
	64	0												
NGPS	225	62	308	83										
	73	11	83	0										
EGRR	6	50	6	108	9	272								
	332	282	332	224	272	0								
GFDN	62	78	33	124	0	0	196	77						
	89	11	108	-16	0	0	77	0						
OTCM	182	68	158	89	3	578	181	75	447	92				
	94	26	99	10	74	-504	83	8	92	0				
CLIP	321	64	265	79	8	279	137	79	331	93	557	266		
	98	34	216	137	98	-181	146	67	239	146	266	0		
HPAC	320	64	258	76	8	279	134	78	318	90	538	245	550	73
	69	5	67	-9	78	-201	75	-3	75	-15	73	-172	73	0

Table 5-7 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMPISPHERE (1 JUL 1997 - 30 JUNE 1998)

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		OTCM		CLIP		HPAC	
JTWC	305	111												
	111	0												
NGPS	213	109	289	131										
	114	5	131	0										
EGRR	134	105	137	105	178	117								
	109	4	113	8	117	0								
GFDN	58	131	29	225	12	122	187	120						
	136	5	167	-58	176	54	120	0						
OTCM	167	113	141	143	61	110	168	116	407	145				
	147	34	153	10	130	20	138	22	145	0				
CLIP	299	111	252	125	151	113	131	123	302	147	516	305		
	148	37	257	132	147	34	199	76	287	140	305	0		
HPAC	297	110	245	120	151	112	128	122	291	143	498	285	510	126
	123	13	121	1	116	4	133	11	131	-12	126	-159	126	0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		OTCM		CLIP		HPAC	
JTWC	273	161												
	161	0												
NGPS	186	160	257	178										
	159	-1	178	0										
EGRR	5	70	5	97	7	389								
	471	401	471	374	389	0								
GFDN	52	187	21	362	0	0	171	162						
	173	-14	207	-155	0	0	162	0						
OTCM	142	169	113	187	3	744	139	161	336	220				
	228	59	228	41	200	-544	217	56	220	0				
CLIP	269	162	227	170	6	416	119	164	254	222	473	346		
	202	40	297	127	175	-241	257	93	320	98	346	0		
HPAC	267	161	220	163	6	416	116	163	246	218	457	327	469	182
	181	20	178	15	130	-286	197	34	188	-30	182	-145	182	0

Table 5-7 1998 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMPISPHERE (1 JUL 1997 - 30 JUNE 1998)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		OTCM		CLIP		HPAC	
JTWC	245	219												
	219	0												
NGPS	164	215	225	227										
	208	-7	227	0										
EGRR	102	215	101	193	141	195								
	183	-32	187	-6	195	0								
GFDN	45	252	16	497	5	214	155	206						
	204	-48	249	-248	250	36	206	0						
OTCM	102	244	75	240	31	197	100	210	247	296				
	306	62	315	75	297	100	290	80	296	0				
CLIP	241	221	201	218	119	183	108	207	187	305	431	372		
	261	40	323	105	266	83	303	96	327	22	372	0		
HPAC	239	219	196	211	119	182	105	205	184	301	416	358	428	244
	248	29	239	28	236	54	267	62	260	-41	245	-113	244	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		OTCM		CLIP		HPAC	
JTWC	81	349												
	349	0												
NGPS	39	325	175	319										
	317	-8	319	0										
EGRR	18	308	76	307	117	272								
	268	-40	284	-23	272	0								
GFDN	31	356	10	646	3	315	120	320						
	289	-67	267	-379	321	6	320	0						
OTCM	30	403	50	379	21	321	54	336	135	437				
	456	53	483	104	433	112	411	75	437	0				
CLIP	80	352	156	314	96	266	84	328	105	456	345	421		
	337	-15	395	81	390	124	416	88	401	-55	421	0		
HPAC	80	352	154	307	97	265	84	328	104	455	337	419	348	380
	416	64	378	71	366	101	429	101	418	-37	380	-39	380	0

Chapter 6
Tropical Cyclone Warning Verification Statistics

6.1 GENERAL

The verification data in this chapter includes best tracks (6-hourly positions and intensities), JTWC forecasts (12-, 24-, 36-, 48- and 72-hour position, intensity and wind radii), and fixes made from satellite, aircraft, radar, and synoptic data. These data are archived and available for download from the JTWC web page. For further information on the JTWC verification statistics, please contact the JTWC Deputy Director via email (address: jtops@npmoc.navy.mil), or letter (address: NAVPACMETOCCEN/JTWC, 425 Luapele Road, Pearl Harbor, HI, 96860-3103.

6.2 WARNING VERIFICATION STATISTICS

6.2.1 NORTH WEST PACIFIC AND NORTH INDIAN OCEAN VERIFICATION TABLES

This section includes 1998 verification statistics for each North West Pacific and North Indian Ocean tropical cyclone that was warned on by JTWC.

Statistics for JTWC on TD 01W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98070600		17.2N	132.3E	15												
98070606		17.5N	132.1E	15												
98070612		18.1N	131.6E	20												
98070618		18.6N	131.1E	20												
98070700		19.1N	130.7E	20												
98070706		19.4N	130.4E	20												
98070712	1	19.6N	130.2E	25	58	89	82	128	168	99	0	5	5	10	20	35
98070718	2	19.7N	130.0E	25	74	59	38	52	39	166	0	0	5	10	15	25
98070800	3	20.0N	129.6E	25	17	75	102	107	169	387	0	0	5	10	15	25
98070806	4	20.3N	129.0E	30	17	68	85	104	185		0	0	5	10	20	
98070812	5	20.8N	128.5E	30	41	78	90	139	222		0	0	5	10	20	
98070818	6	21.3N	128.2E	30	66	93	109	167	249		0	0	5	15	20	
98070900	7	21.6N	128.0E	30	16	58	61	18	42		0	0	5	15	20	
98070906	8	21.8N	127.7E	30	8	34	58	91			0	0	10	15		
98070912	9	21.9N	127.3E	30	5	66	111	181			0	0	5	20		

Statistics for JTWC on TD 01W

98070918	10	22.2N	126.7E	30	11	46	90				0	5	10			
98071000	11	22.7N	125.7E	30	8	32	63				0	10	20			
98071006	12	23.3N	124.7E	25	0	8					0	5				
98071012	13	24.0N	123.8E	25	0	44					0	0				
98071018	14	24.6N	122.6E	25	8						0					
98071100	15	25.1N	121.3E	25	0						0					
			AVERAGE		22	58	81	110	153	217	0	2	7	13	19	28
			BIAS								0	2	7	13	19	28
			# CASES		15	13	11	9	7	3	15	13	11	9	7	3

Statistics for JTWC on TS 02W Nichole

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98070700		18.3N	117.0E	15												
98070706		18.8N	117.4E	20												
98070712		19.5N	117.8E	20												
98070718		20.2N	118.2E	20												
98070800	1	21.0N	118.5E	25	17	57	78	102	81	45	0	0	-5	-20	5	10
98070806	2	21.6N	118.7E	30	16	53	95	89	78	65	0	0	-10	-5	15	20
98070812	3	22.0N	119.0E	30	17	57	97	110	147		0	0	-15	0	0	
98070818	4	22.4N	119.4E	35	40	84	111	138	166		0	-5	-10	5	0	
98070900	5	22.6N	119.7E	35	56	84	90	101	98	113	0	-10	15	20	10	0
98070906	6	22.9N	120.1E	45	61	43	58	73	70	82	-10	-5	20	15	10	0
98070912	7	23.0N	120.1E	50	35	36	91	107	119		-5	20	30	15	0	
98070918	8	23.1N	119.9E	45	11	37	63	78	115		0	25	30	25	0	
98071000	9	23.0N	119.7E	30	37	79	76	74	103		5	10	15	20	-5	
98071006	10	22.9N	119.4E	25	62	97	126				5	10	-5			
98071012	11	22.8N	119.1E	25	85	103	120				0	0	-5			
98071018	12	22.9N	118.8E	25	88	85					0	-5				
98071106	13	23.2N	118.5E	25	66	98	123	193			0	0	0	5		
98071118	14	23.4N	118.2E	25	63	62	116				0	0	5			
98071206	15	23.6N	118.0E	25	49	135					0	5				
98071218	16	25.1N	118.1E	20	0						0					
			AVERAGE		44	74	96	106	108	76	2	6	13	13	5	8
			BIAS								0	3	5	8	4	8
			# CASES		16	15	13	10	9	4	16	15	13	10	9	4

Statistics for JTWC on TS 03W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98072218		17.0N	144.1E	10												
98072300		17.2N	144.3E	15												
98072306		17.5N	144.6E	15												
98072312		18.4N	145.3E	15												
98072318		19.4N	146.1E	15												

Statistics for JTWC on TS 03W

98072400		20.7N	147.2E	25												
98072406		21.9N	148.2E	25												
98072412		23.4N	149.1E	25												
98072418		25.2N	149.3E	25												
98072500	1	26.9N	149.1E	25	33	151	302				0	-15	5			
98072506	2	28.9N	148.5E	30	12	130	250				0	-10	10			
98072512	3	30.9N	147.2E	45	0	94					-15	0				
98072518	4	32.5N	145.9E	40	15	99					-10	5				
98072600	5	34.5N	144.8E	30	5						0					
98072606	6	36.2N	144.5E	25	17						0					
			AVERAGE		14	118	276				4	8	8			
			BIAS								-4	-5	8			
			# CASES		6	4	2				6	4	2			

Statistics for JTWC on TY 04W Otto

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98080106		14.1N	128.0E	20												
98080112		14.3N	127.7E	20												
98080118		14.6N	127.1E	20												
98080200	1	14.9N	126.5E	30	13	29	62	122	141	166	0	0	0	-15	-35	30
98080206	2	15.2N	126.0E	30	41	93	164	213	259	302	0	0	-10	-30	-15	45
98080212	3	15.7N	125.5E	35	71	117	178	211	271		0	-5	-20	-50	-5	
98080218	4	16.6N	124.9E	35	61	127	198	258	306		0	-15	-35	-20	-10	
98080300	5	17.7N	124.4E	45	49	114	168	240	253		-10	-20	-45	5	25	
98080306	6	18.9N	123.8E	55	16	53	93	130	133		-10	-25	-5	10	55	
98080312	7	20.1N	123.2E	65	13	13	66	61			0	-25	25	35		
98080318	8	21.2N	122.5E	80	11	25	60	60			-15	5	15	10		
98080400	9	22.1N	121.9E	100	8	90	116				-35	0	15			
98080406	10	23.3N	121.2E	70	18	63	87				-5	0	30			
98080412	11	24.5N	120.3E	60	6	52					0	10				
98080418	12	25.2N	119.6E	65	12	65					0	20				
98080500	13	25.8N	118.7E	50	8						0					
98080506		26.5N	118.0E	30												
			AVERAGE		26	70	119	162	227	234	6	10	20	22	24	38
			BIAS								-6	-5	-3	-7	3	38
			# CASES		13	12	10	8	6	2	13	12	10	8	6	2

Statistics for JTWC on TS 05W Penny

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98080506		10.2N	129.9E	15												
98080512		10.7N	129.4E	15												
98080518		11.3N	128.9E	20												
98080600		12.0N	128.4E	25												

Statistics for JTWC on TS 05W Penny

98080606	1	12.7N	127.9E	25	21	58	76	109			0	0	0	-5		
98080618	2	14.3N	126.4E	25	11	43	75	111			0	0	-5	0		
98080706	3	15.8N	125.0E	30	0	18	49	73			-5	-10	-5	0		
98080718	4	17.0N	123.1E	35	12	31	34	80	116	176	0	0	5	5	10	-25
98080800	5	17.4N	122.1E	35	6	55	92	105	90	94	0	0	0	0	10	0
98080806	6	17.8N	121.1E	30	18	57	80	62	78	88	0	5	10	10	5	10
98080812	7	18.3N	120.1E	30	8	34	34	13	58	86	0	0	5	10	0	0
98080818	8	18.8N	119.0E	30	11	18	46	90	120		5	5	0	5	-25	
98080900	9	19.1N	117.9E	35	8	21	36	80	62		0	0	5	-5	-15	
98080906	10	19.4N	116.8E	35	11	68	110	107			0	-5	-10	-30		
98080912	11	19.7N	116.0E	40	8	13	42	40			0	0	-10	-15		
98080918	12	20.0N	115.3E	45	5	42	83	64			0	0	-5	-5		
98081000	13	20.2N	114.5E	45	17	68	55	66			0	-15	-10	-5		
98081006	14	20.3N	113.5E	50	28	61	35				-5	-5	-5			
98081012	15	20.4N	112.4E	60	5	51	73	98			-10	5	5	5		
98081018	16	20.7N	111.6E	55	12	74	72				-10	5	5			
98081100	17	21.5N	111.2E	45	12	79	148				10	5	5			
98081106	18	22.4N	110.5E	35	8	42					0	-5				
98081112		23.0N	109.4E	30												
98081118		23.5N	108.2E	25												
98081200		23.8N	107.0E	20												
			AVERAGE		12	46	67	78	88	111	3	4	5	7	11	9
			BIAS								-1	-1	-1	-2	-3	-4
			# CASES		18	18	17	14	6	4	18	18	17	14	6	4

Statistics for JTWC on TY 06W Rex

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98082212		16.6N	130.5E	20												
98082218		16.7N	129.4E	25												
98082300		17.4N	128.6E	30												
98082306		18.5N	128.7E	35												
98082312		19.5N	129.4E	35												
98082318		20.6N	130.0E	35												
98082400	1	21.5N	130.5E	35	71	115	156	159	199	349	-5	-5	-10	-20	-30	-45
98082406	2	22.3N	131.1E	35	98	126	145	164	248	402	-5	-10	-15	-20	-35	-45
98082412	3	22.9N	131.6E	35	40	61	94	183	276	416	-5	-10	-15	-25	-45	-50
98082418	4	23.6N	132.1E	40	38	62	122	225	327	421	-10	-15	-20	-35	-45	-55
98082500	5	24.2N	132.6E	45	20	75	182	300	423	547	-10	-15	-25	-40	-35	-55
98082506	6	24.5N	133.1E	50	16	66	161	270	353	436	-15	-20	-40	-45	-40	-60
98082512	7	24.7N	133.7E	55	31	108	210	322	380	470	-10	-20	-35	-30	-35	-50
98082518	8	24.8N	134.3E	60	36	90	207	287	349	482	-15	-30	-35	-30	-40	-65
98082600	9	24.8N	135.4E	70	0	29	91	129	176	269	-15	-25	-15	-15	-20	-10
98082606	10	24.8N	136.2E	80	13	55	83	116	157	250	-5	0	10	5	0	15
98082612	11	24.7N	137.0E	90	8	25	43	82	120	276	0	10	10	5	5	25
98082618	12	24.5N	137.7E	90	6	56	64	60	32	150	0	10	5	0	5	30
98082700	13	24.6N	138.5E	90	16	45	33	60	116	248	0	0	-5	-5	0	15

Statistics for JTWC on TY 06W Rex

98082706	14	25.0N	139.2E	90	0	19	45	77	160	328	0	-10	-15	-5	5	15
98082712	15	25.5N	139.8E	100	5	8	42	102	156	308	0	-10	-10	0	15	20
98082718	16	25.9N	140.1E	105	8	32	24	68	121	277	-5	-15	-10	5	20	20
98082800	17	26.4N	140.5E	110	8	42	96	150	200	347	-20	-15	-5	5	15	-20
98082806	18	26.9N	140.8E	115	12	48	97	160	258	641	0	0	10	15	20	-15
98082812	19	27.4N	140.9E	115	12	43	109	207	319	754	0	5	15	25	20	-15
98082818	20	27.8N	140.9E	115	12	60	141	235	395	884	0	10	20	25	20	-20
98082900	21	28.1N	140.9E	110	6	21	134	272	445	1005	0	10	20	20	-15	-50
98082906	22	28.5N	140.9E	105	12	87	206	373	552	1178	5	15	20	0	-25	-50
98082912	23	28.8N	140.9E	100	0	35	171	326	543	1131	0	10	5	0	-25	-50
98082918	24	29.2N	141.0E	95	8	38	187	377	627	1200	-5	5	5	0	-30	-50
98083000	25	29.6N	141.2E	90	12	42	140	324	572	1121	0	0	0	-10	-35	-45
98083006	26	30.1N	141.4E	90	10	71	194	403	646	1125	0	0	0	-15	-35	-40
98083012	27	30.5N	141.8E	90	8	58	204	420	676	1104	0	0	0	-20	-35	-35
98083018	28	30.9N	142.4E	90	6	57	229	471	729	1086	0	0	-10	-20	-40	-30
98083100	29	31.3N	143.1E	90	10	68	192	381	562	834	0	0	-15	-20	-35	-25
98083106	30	31.5N	144.0E	90	7	60	161	324	459	757	0	-5	-15	-20	-30	-20
98083112	31	31.3N	144.9E	90	18	80	164	252	309	480	0	-10	-15	-15	-25	-15
98083118	32	30.9N	146.0E	95	15	57	101	132	130	86	-5	-10	-15	-10	-10	5
98090100	33	30.5N	147.1E	100	7	32	59	84	94	164	0	0	-5	-5	-5	5
98090106	34	29.9N	148.2E	100	13	40	53	91	104	189	0	0	0	0	0	5
98090112	35	29.3N	149.2E	100	16	16	59	74	72	209	0	5	5	5	5	5
98090118	36	29.0N	150.2E	100	20	84	151	177	152	158	0	5	10	10	5	10
98090200	37	28.9N	151.3E	95	8	48	91	78	44	119	-5	5	15	10	5	20
98090206	38	29.4N	152.2E	90	0	16	5	57	140	237	0	10	10	10	5	20
98090212	39	29.8N	153.1E	85	0	17	72	139	225	300	5	15	15	10	5	15
98090218	40	30.4N	153.7E	80	7	55	138	234	327	369	0	10	10	5	5	5
98090300	41	30.9N	154.0E	75	6	39	103	214	315	423	5	15	10	5	10	5
98090306	42	31.3N	154.4E	70	0	31	94	155	220	323	-5	0	-5	-5	-5	-10
98090312	43	31.4N	154.8E	65	0	27	93	129	173	137	0	0	-5	0	-10	-15
98090318	44	31.5N	155.2E	65	0	33	74	85	106	141	0	0	-5	-5	-10	-20
98090400	45	31.5N	155.7E	65	10	36	40	67	150	698	0	0	0	0	-5	-10
98090406	46	31.5N	156.4E	65	0	33	96	162	236	718	0	5	0	0	-5	-10
98090412	47	31.6N	157.0E	65	11	70	176	270	389	888	0	10	0	0	-5	-10
98090418	48	31.8N	157.4E	60	5	34	103	201	454	821	5	5	0	-5	-10	-10
98090500	49	32.2N	157.7E	55	18	61	133	278	601	746	0	0	-5	-5	-10	-10
98090506	50	32.8N	157.9E	55	0	21	63	306	567	527	0	0	-5	-5	-10	-10
98090512	51	33.5N	158.1E	55	9	54	191	476	589	434	0	0	-10	-10	-20	-25
98090518	52	34.4N	158.4E	55	28	112	363	605	626	553	0	0	-10	-15	-15	-20
98090600	53	35.5N	159.0E	55	12	117	367	423	294	322	0	0	-10	-15	-15	-20
98090606	54	36.8N	159.9E	55	11	179	366	327	145		0	0	-10	-10	-10	
98090612	55	39.0N	161.6E	55	27	197	229	168	197		0	-5	-10	-10	-15	
98090618	56	41.9N	163.7E	55	58	134	203	395			0	-5	0	-5		
98090700	57	45.2N	165.9E	55	36	142	405	596			0	-5	-5	-15		
98090706		47.6N	167.5E	55												
98090712		49.3N	168.8E	55												
98090718		50.0N	169.8E	50												

Statistics for JTWC on TY 06W Rex																
98090800		50.3N	170.7E	50												
98090806		50.1N	172.7E	50												
98090812		49.9N	176.1E	55												
98090818		49.5N	179.9W	50												
98090900		48.6N	174.8W	50												
			AVERAGE		15	61	140	232	313	525	3	7	11	12	18	25
			BIAS								-2	-1	-4	-6	-12	-16
			# CASES		57	57	57	57	55	53	57	57	57	57	55	53

Statistics for JTWC on TD 07W																
	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98083106		22.6N	122.4E	20												
98083112		23.4N	122.7E	20												
98083118		24.2N	123.3E	20												
98090100		24.7N	124.4E	25												
98090106		24.8N	126.0E	25												
98090112		25.3N	127.8E	25												
98090118		26.0N	129.2E	25												
98090200		26.6N	130.3E	25												
98090206	1	27.3N	131.4E	30	0	44	119	164	213	425	0	0	0	0	0	0
98090212	2	27.9N	133.0E	30	0	74	85	91	111	348	0	0	0	0	0	5
98090218	3	28.3N	134.4E	30	33	125	138	124	133	390	0	0	0	0	0	5
98090300	4	29.1N	136.6E	30	0	63	156	272	406	663	0	0	0	0	0	10
98090318	5	30.2N	140.0E	30	97	200	266	353	418		0	0	0	0	5	
98090400	6	30.4N	140.9E	30	11	34	121	215	316		0	0	0	5	10	
98090406	7	30.6N	141.8E	30	0	48	128				0	0	0			
98090412		30.5N	142.7E	30												
98090418		30.1N	143.5E	30												
98090500		29.6N	144.3E	30												
98090506		29.0N	145.1E	30												
98090512		28.4N	145.8E	25												
98090518		27.5N	146.6E	25												
98090600		26.7N	147.8E	20												
98090606		26.0N	149.5E	15												
			AVERAGE		21	84	145	203	266	457	0	0	0	1	3	5
			BIAS								0	0	0	1	3	5
			# CASES		7	7	7	6	6	4	7	7	7	6	6	4

Statistics for JTWC on TY 08W Stella																
	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98091000		17.0N	149.6E	25												
98091006		16.9N	149.1E	25												
98091012		16.8N	148.4E	20												

Statistics for JTWC on TY 08W Stella

98091018		16.8N	147.9E	20												
98091100		16.8N	147.3E	20												
98091106		16.8N	146.7E	20												
98091112		17.0N	146.0E	20												
98091118		17.3N	145.5E	20												
98091200		17.7N	145.1E	25												
98091206	1	18.4N	144.6E	25	6	59	124	118	156	249	0	0	0	-5	-10	-5
98091212	2	19.2N	144.1E	25	13	34	56	86	136	196	0	0	-10	-15	-15	-10
98091218	3	20.1N	143.2E	30	17	66	72	120	184	268	-5	-5	-10	-15	-20	-10
98091300	4	21.0N	142.3E	30	17	40	71	86	102	310	-5	-15	-20	-20	-20	-10
98091306	5	21.9N	141.5E	35	5	45	28	56	112	398	0	-5	-15	-25	-20	-15
98091312	6	22.5N	140.9E	45	8	41	94	136	206	642	0	0	5	10	25	30
98091318	7	23.1N	140.4E	45	48	146	218	300	366	949	0	0	0	10	25	30
98091400	8	23.9N	139.5E	55	49	92	145	123	126		0	0	0	10	25	
98091406	9	24.9N	138.7E	55	49	110	133	84	58		0	-5	0	10	10	
98091412	10	25.8N	137.9E	60	44	72	68	64	192		0	0	5	10	10	
98091418	11	26.8N	137.1E	65	37	37	46	37	188		-5	0	5	5	0	
98091500	12	28.1N	136.4E	65	29	28	76	61			0	0	-10	0		
98091506	13	30.0N	136.3E	65	0	63	60	211			0	0	-5	0		
98091512	14	32.1N	136.9E	65	8	34	129				0	-5	-5			
98091518	15	34.1N	138.3E	65	19	68	396				0	0	-5			
98091600	16	36.3N	139.6E	65	30	142					0	0				
98091606	17	39.8N	141.8E	60	40	151					0	0				
98091612	18	43.6N	146.5E	60	24						0					
98091618		46.0N	154.0E	60												
			AVERAGE		25	72	114	114	166	430	1	2	6	10	16	16
			BIAS								-1	-2	-4	-2	1	1
			# CASES		18	17	15	13	11	7	18	17	15	13	11	7

Statistics for JTWC on TD 09W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98091218		20.1N	113.7E	20												
98091300		20.1N	112.6E	25												
98091306	1	20.1N	111.3E	25	22	108	147	166			0	0	10	15		
98091312	2	20.2N	109.8E	25	6	43	46				0	0	10			
98091318	3	20.4N	108.3E	25	5	33	67				0	5	5			
98091400		20.4N	107.2E	25												
98091406		20.3N	106.2E	20												
98091412		20.5N	105.3E	15												
98091418		21.0N	104.6E	15												
			AVERAGE		11	62	87	166			0	2	8	15		
			BIAS								0	2	8	15		
			# CASES		3	3	3	1			3	3	3	1		

Statistics for JTWC on STY 10W Todd

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98091418		19.4N	126.1E	20												
98091500		19.6N	127.3E	25												
98091506		19.9N	128.5E	30												
98091512		20.1N	129.6E	35												
98091518		20.3N	130.4E	40												
98091600	1	20.6N	131.3E	45	62	74	96	53	167	632	-10	-25	-75	-65	-15	10
98091606	2	20.9N	132.1E	50	16	12	72	211	414	672	-5	-40	-75	-40	-5	15
98091612	3	21.3N	132.8E	65	13	18	49	263	429	713	-5	-55	-55	-10	5	20
98091618	4	21.7N	133.5E	90	11	50	176	376	507	740	-20	-50	-15	15	25	50
98091700	5	22.3N	134.2E	120	0	30	223	374	476	648	-5	5	50	70	70	95
98091706	6	23.3N	134.7E	130	5	94	274	364	467	735	-10	30	50	40	50	20
98091712	7	24.6N	135.0E	120	0	172	299	407	561	758	0	40	45	40	35	20
98091718	8	26.5N	134.5E	100	13	115	235	475	746	1119	5	25	20	10	10	20
98091800	9	28.9N	133.1E	80	12	177	309	401	433		-10	-15	-25	-25	-10	
98091806	10	29.8N	131.1E	70	47	59	115	197	312		-5	-15	-15	-10	-5	
98091812	11	30.3N	129.1E	65	26	17	94	189	258		0	-10	-15	-5	-5	
98091818	12	30.4N	127.4E	65	6	68	143	269	303		0	-5	0	0	0	
98091900	13	30.2N	125.7E	60	7	36	34	114			5	10	20	10		
98091906	14	30.0N	124.1E	55	11	48	114	225			10	20	15	10		
98091912	15	29.8N	122.9E	55	10	16	150				0	10	0			
98091918	16	29.8N	121.8E	40	0	56	182				15	15	0			
98092000	17	29.5N	121.0E	35	5	107					5	0				
98092006		29.1N	121.2E	30												
98092012		29.4N	122.0E	30												
98092018		30.2N	122.9E	25												
			AVERAGE		15	68	160	280	423	752	6	22	30	25	20	31
			BIAS								-2	-4	-5	3	13	31
			# CASES		17	17	16	14	12	8	17	17	16	14	12	8

Statistics for JTWC on TY 11W Vicki

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98091600		17.3N	117.9E	20												
98091606		17.1N	118.2E	20												
98091612		17.0N	118.5E	20												
98091618		17.0N	118.8E	25												
98091700	1	16.9N	118.9E	30	69	124	148	153	143	133	0	-10	-30	-45	-50	-15
98091706	2	16.7N	118.8E	30	67	135	171	200	169	150	0	-20	-40	-55	-10	-5
98091712	3	16.5N	118.7E	35	59	87	108	132	132	314	0	-20	-30	-40	0	-5
98091718	4	16.3N	118.8E	45	18	73	147	253	395	682	0	-20	-30	10	25	15
98091800	5	16.1N	119.1E	55	18	64	158	334	481	742	-5	-10	-10	35	35	35
98091806	6	16.0N	119.4E	65	23	87	222	390	538	753	0	-15	25	45	40	40
98091812	7	16.0N	119.7E	70	31	86	231	384	540	792	0	-5	35	35	35	30
98091818	8	16.0N	120.0E	85	6	83	196	344	442	701	0	35	25	-5	5	-15

Statistics for JTWC on TY 11W Vicki

98091900	9	16.2N	120.7E	80	5	89	188	304	362	542	0	30	25	30	35	20
98091906	10	16.7N	121.7E	50	8	83	169	215	274	565	0	25	15	30	35	20
98091912	11	17.5N	123.2E	45	98	223	318	327	362	752	0	10	10	25	25	30
98091918	12	18.1N	124.3E	40	20	127	188	263	351	889	0	10	10	25	10	55
98092000	13	19.6N	125.6E	55	13	46	60	80	138	779	0	5	5	5	0	20
98092006	14	21.0N	126.9E	55	17	46	67	79	206		0	5	5	-10	-5	
98092012	15	22.4N	128.0E	60	8	45	80	98	369		0	0	-5	-10	5	
98092018	16	23.5N	129.0E	60	33	57	75	181	556		0	0	-20	-10	30	
98092100	17	24.8N	130.2E	65	24	56	54	263	406		0	0	-15	-15	0	
98092106	18	26.2N	131.3E	65	8	24	123	428			0	-15	-15	10		
98092112	19	27.7N	132.3E	75	0	60	269	464			0	-15	-10	10		
98092118	20	29.6N	133.1E	90	0	108	402				0	0	25			
98092200	21	32.2N	134.0E	90	0	164	322				0	-15	5			
98092206	22	35.0N	136.0E	90	0	144					0	10				
98092212	23	38.4N	139.6E	80	15	69					0	15				
98092218	24	41.8N	144.1E	55	90						0					
98092300	25	43.8N	147.7E	55	0						0					
			AVERAGE		26	90	176	258	345	600	0	13	19	24	20	23
			BIAS								0	0	-1	4	13	17
			# CASES		25	23	21	19	17	13	25	23	21	19	17	13

Statistics for JTWC on TD 12W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98091618		16.0N	110.2E	20												
98091700		16.1N	109.9E	20												
98091706		16.2N	109.7E	20												
98091712		16.3N	109.4E	20												
98091718		16.4N	108.8E	20												
98091800		16.5N	108.4E	25												
98091806	1	16.7N	108.0E	30	26	31	31	63			0	10	10	-5		
98091812	2	17.1N	107.5E	25	13	6	26				0	5	10			
98091818	3	17.4N	107.1E	25	13	13	21				0	0	0			
98091900	4	17.8N	106.8E	25	39	85					0	0				
98091906	5	18.2N	106.6E	30	43	59					0	5				
98091912	6	18.6N	106.2E	25	21						0					
98091918	7	18.7N	105.7E	25	0						0					
			AVERAGE		23	39	26	63			0	4	7	5		
			BIAS								0	4	7	-5		
			# CASES		7	5	3	1			7	5	3	1		

Statistics for JTWC on TS 13W Waldo

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98091818		19.6N	136.9E	15												

Statistics for JTWC on TS 13W Waldo

98091900		20.2N	137.5E	20												
98091906		20.9N	137.8E	20												
98091912		21.9N	138.0E	25												
98091918		22.9N	138.1E	25												
98092000	1	23.9N	137.9E	30	49	117	260	492			0	0	5	15		
98092006	2	24.8N	137.3E	35	29	104	252	441			-5	-5	-5	15		
98092012	3	26.2N	136.8E	35	60	198	394				-5	-5	5			
98092018	4	27.9N	136.4E	40	11	132	511				-5	-5	5			
98092100	5	30.1N	136.0E	40	10	61					0	10				
98092106	6	32.7N	136.0E	45	16	37					-5					
98092112	7	35.4N	136.4E	35	30						5					
98092118	8	38.0N	137.2E	30	0						0					
			AVERAGE		26	108	354	466			3	4	5	15		
			BIAS								-2	-1	3	15		
			# CASES		8	6	4	2			8	6	4	2		

Statistics for JTWC on TY 14W Yanni

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98092406		12.9N	134.2E	15												
98092412		13.7N	133.5E	20												
98092418		14.6N	132.8E	20												
98092500	1	15.5N	131.9E	25	69	181	277	350	386	447	5	0	5	5	10	-10
98092506	2	16.5N	130.7E	30 1	16	254	352	425	484	565	0	0	5	5	10	-20
98092512	3	17.5N	129.5E	30	41	145	236	291	364	420	0	0	5	5	5	-25
98092518	4	18.2N	128.3E	30	85	184	271	334	402	438	0	0	5	5	-5	-30
98092600	5	18.8N	127.2E	30 1	45	236	288	353	381	394	0	0	0	0	-15	-35
98092606	6	19.4N	126.4E	30	8	42	46	29	50	197	0	5	15	10	-5	-35
98092612	7	20.0N	125.5E	30	17	36	62	78	106	310	0	5	10	0	-10	-25
98092618	8	20.5N	124.9E	30	17	30	34	56	110	383	0	5	0	-10	-15	-20
98092700	9	21.0N	124.3E	30	63	122	151	167	235	617	0	-5	-20	-35	-40	-10
98092706	10	21.5N	123.7E	30	16	41	38	101	205	566	0	-10	-25	-30	-40	-15
98092712	11	22.0N	122.9E	35	31	19	50	134	275	552	0	-15	-20	-45	-35	5
98092718	12	22.5N	122.4E	45	23	63	112	217	401	574	-5	-30	-45	-50	-30	0
98092800	13	23.2N	122.3E	55	20	55	130	275	487	490	-10	-25	-45	-45	-25	5
98092806	14	23.8N	122.4E	65	12	44	123	270	391	218	0	0	5	30	50	90
98092812	15	24.5N	122.6E	70	16	62	179	355	367	177	5	10	30	60	80	95
98092818	16	25.3N	123.0E	75	16	84	222	348	285	109	0	10	40	65	85	95
98092900	17	26.3N	123.6E	80	16	88	253	246	147	361	-5	10	35	40	35	30
98092906	18	27.4N	124.4E	80	8	114	203	114	108		0	15	25	30	30	
98092912	19	28.8N	125.5E	75	8	116	83	233	521		5	10	10	15	15	
98092918	20	30.9N	126.2E	65	36	154	412	777	1254		5	0	10	15	15	
98093000	21	33.2N	126.8E	55	43	182	451	819	1255		10	10	15	15	20	
98093006	22	34.4N	127.1E	50	24	128	293	477			0	5	10	5		
98093012	23	34.6N	127.3E	40	13	83	222	385			-5	0	5	5		

Statistics for JTWC on TY 14W Yanni

98093018	24	34.4N	127.5E	35	17	111	238				0	5	0			
98100100	25	33.9N	127.9E	30	15	108	240				0	5	5			
98100106	26	33.0N	128.1E	25	10	70					0	0				
98100112		32.0N	128.4E	25												
98100118		30.9N	128.6E	25												
98100200		29.7N	128.9E	20												
			AVERAGE		35	106	199	297	391	401	2	7	16	23	27	32
			BIAS								0	0	3	4	6	6
			# CASES		26	26	25	23	21	17	26	26	25	23	21	17

Statistics for JTWC on TD 15W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98100200		12.0N	113.0E	25												
98100206		12.5N	113.5E	25												
98100212		13.0N	114.0E	25												
98100218		13.6N	114.3E	25												
98100300		14.2N	114.1E	25												
98100306	1	14.7N	113.8E	30	21	75	145	216	296		0	5	5	10	15	
98100312	2	15.2N	113.3E	30	29	38	80	142	175		0	5	10	15	20	
98100318	3	15.7N	112.8E	30	29	51	112	183	176		0	5	10	15	25	
98100400	4	16.3N	112.1E	30	29	53	92	129			0	5	10	15		
98100406	5	16.9N	111.1E	30	12	82	138	114			0	5	10	20		
98100412	6	17.5N	110.1E	30	13	24	32				0	5	5			
98100418	7	18.0N	108.9E	30	49	59	46				0	0	0			
98100500	8	18.4N	107.7E	30	6	13					0	0				
98100506	9	18.7N	106.5E	30	20	0					0	0				
98100512	10	18.9N	105.7E	30	34						0					
98100518	11	19.0N	105.2E	25	18						0					
			AVERAGE		24	44	92	157	215		0	3	7	15	20	
			BIAS								0	3	7	15	20	
			# CASES		11	9	7	5	3		11	9	7	5	3	

Statistics for JTWC on TD 16W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98100400		23.8N	122.2E	15												
98100406		23.8N	122.3E	15												
98100412		23.9N	122.4E	20												
98100418		24.0N	122.5E	20												
98100500		24.1N	122.6E	25												
98100506	1	24.1N	122.7E	25	12	29	34	36	97		0	5	5	5	5	
98100512	2	24.1N	122.8E	25	34	34	29	45	109		0	5	0	5	5	
98100518	3	24.1N	122.8E	25	18	13	16	40	89		0	5	5	5	10	
98100600	4	24.3N	122.8E	25	16	29	42	69			0	0	0	5		

Statistics for JTWC on TD 16W

98100606	5	24.4N	122.8E	25	16	38	63	98			0	0	0	10		
98100612	6	24.6N	122.8E	30	8	34	78				0	0	5			
98100618	7	24.9N	122.9E	30	12	62	115				0	0	5			
98100700	8	25.1N	123.2E	30	8	24					0	0				
98100706	9	25.3N	123.7E	30	13	48					0	5				
98100712	10	25.4N	124.2E	30	20						0					
98100718	11	25.4N	124.7E	25	34						0					
			AVERAGE		18	35	54	58	98		0	2	3	6	7	
			BIAS								0	2	3	6	7	
			# CASES		11	9	7	5	3		11	9	7	5	3	

Statistics for JTWC on TD 17W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98100506		28.1N	125.6E	20												
98100512		28.5N	125.7E	20												
98100518		29.0N	125.8E	25												
98100600	1	29.5N	126.0E	30	0	36	85				0	10	15			
98100606	2	29.7N	126.1E	25	5	35					0	5				
98100612	3	29.9N	126.2E	20	5	8					5	10				
98100618	4	30.0N	126.3E	20	0						5					
98100700	5	30.1N	126.4E	15	0						5					
			AVERAGE		2	27	85				3	8	15			
			BIAS								3	8	15			
			# CASES		5	3	1				5	3	1			

Statistics for JTWC on STY 18W Zeb

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98100718		11.2N	151.0E	15												
98100800		11.0N	149.8E	15												
98100806		10.9N	148.7E	15												
98100812		10.9N	147.3E	20												
98100818		10.8N	145.8E	20												
98100900		10.8N	144.4E	20												
98100906		10.8N	143.2E	20												
98100912		10.8N	142.4E	25												
98100918	1	10.8N	141.8E	25	56	57	48	60	100	211	0	-5	-10	-15	-30	-60
98101000	2	10.8N	141.2E	30	17	66	109	164	216	325	0	-5	-5	-10	-35	-75
98101006	3	10.8N	140.3E	35	35	90	131	183	212	326	-5	-5	-5	-20	-40	-80
98101012	4	10.6N	139.3E	40	37	8	24	41	84	184	-5	-10	-10	-35	-50	-85
98101018	5	10.7N	138.2E	45	23	47	77	118	176	243	-5	-10	-20	-40	-60	-80
98101100	6	10.7N	137.2E	50	24	63	59	102	160	184	0	-5	-30	-45	-70	-80
98101106	7	10.7N	136.0E	55	0	13	13	53	104	103	-5	-20	-40	-60	-80	-45
98101112	8	10.9N	134.8E	60	11	32	100	173	182	98	-5	-30	-40	-60	-65	-30

Statistics for JTWC on STY 18W Zeb

98101118	9	11.1N	133.6E	75	18	54	114	162	147	101	-15	-35	-50	-65	-60	-25
98101200	10	11.4N	132.4E	90	26	78	132	142	120	64	-15	-25	-40	-45	-40	40
98101206	11	12.2N	131.2E	100	13	42	84	101	77	72	-25	-40	-50	-45	-5	35
98101212	12	12.9N	129.9E	110	5	27	53	66	108	85	-20	-45	-55	-45	15	35
98101218	13	13.8N	128.7E	125	18	61	99	105	146	73	-25	-45	-45	-5	30	40
98101300	14	14.8N	127.4E	140	39	69	83	146	204	193	10	0	-15	20	30	30
98101306	15	15.5N	126.1E	150	8	49	121	186	200	66	0	-5	20	30	20	15
98101312	16	16.0N	124.7E	155	5	29	94	156	168	108	0	-5	40	35	30	20
98101318	17	16.5N	123.5E	155	13	17	73	78	83	114	0	30	50	30	30	30
98101400	18	17.0N	122.7E	155	12	24	66	60	61	161	0	0	25	30	10	10
98101406	19	17.4N	122.0E	120	29	62	56	54	106	304	-5	10	20	20	5	0
98101412	20	17.7N	121.4E	100	8	44	122	187	292	547	0	15	30	20	10	5
98101418	21	18.2N	121.1E	90	36	46	49	75	188	568	10	20	30	15	20	5
98101500	22	19.0N	120.9E	85	23	36	61	141	251	799	0	10	5	-5	5	0
98101506	23	20.1N	121.0E	90	32	36	6	99	199	838	0	10	0	5	0	0
98101512	24	21.2N	121.1E	80	18	11	72	176	364	1008	0	-5	-10	-5	-10	0
98101518	25	22.4N	121.3E	80	37	33	72	181	434		0	-15	-5	-10	-10	
98101600	26	23.8N	121.9E	80	0	45	108	226	496		0	-10	-10	-15	-15	
98101606	27	25.3N	122.8E	85	0	69	85	255	543		0	0	-10	-20	-15	
98101612	28	26.5N	124.6E	80	0	28	30	259	387		0	-5	-10	-20	-15	
98101618	29	27.5N	126.5E	70	0	40	152	403			0	-10	-15	-10		
98101700	30	29.0N	128.2E	70	13	126	361	477			-5	-10	-15	-10		
98101706	31	30.7N	130.1E	70	20	180	423				-10	-15	-5			
98101712	32	33.1N	132.7E	65	41	243	358				-5	-5	-5			
98101718	33	36.0N	135.5E	65	54	198					-5	5				
98101800	34	40.4N	137.9E	60	33	132					-10	-5				
98101806		43.7N	141.1E	50												
98101812		45.8N	145.0E	50												
			AVERAGE		21	63	107	154	207	282	5	14	23	26	29	34
			BIAS								-4	-8	-9	-13	-14	-12
			# CASES		34	34	32	30	28	24	34	34	32	30	28	24

Statistics for JTWC on TS 19W Alex

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98101006		13.1N	148.8E	45												
98101012		13.6N	147.4E	50												
98101018		14.2N	145.5E	50												
98101100	1	14.5N	143.6E	45	16	45	158	267			-5	0	5	5		
98101106	2	15.1N	141.8E	45	8	75	234	324			-5	5	5	10		
98101112	3	15.8N	139.7E	40	37	173	285				0	5	0			
98101118	4	16.7N	137.4E	35	70	247	368				0	5	5			
98101200	5	17.7N	134.4E	30	30	127					0	-5				
98101206	6	18.2N	131.2E	30	16	309					0	0				
98101212	7	17.0N	128.3E	30	18						0					
98101218	8	14.3N	127.0E	25	87						0					
			AVERAGE		36	163	261	295			1	3	4	8		

Statistics for JTWC on TS 19W Alex																
			BIAS								-1	2	4	8		
			# CASES		8	6	4	2			8	6	4	2		

Statistics for JTWC on STY 20W Babs																
	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98101118		12.1N	149.2E	20												
98101200		12.5N	148.3E	20												
98101206		12.5N	147.1E	20												
98101212		12.2N	145.9E	20												
98101218		11.9N	144.9E	20												
98101300		11.6N	143.8E	20												
98101306		11.6N	142.9E	20												
98101312		11.6N	142.0E	25												
98101318		11.7N	140.9E	25												
98101400		11.7N	139.7E	25												
98101406	1	11.7N	138.8E	25	42	46	55	66	104	173	0	0	0	-5	0	10
98101412	2	11.7N	137.9E	25	50	77	82	119	208	365	0	0	-5	-5	0	15
98101418	3	11.7N	137.0E	30	38	31	56	91	193	511	0	0	-10	-5	0	15
98101500	4	11.8N	136.1E	30	8	21	13	83	149	341	0	-5	-5	-5	0	10
98101506	5	11.9N	135.2E	35	0	47	18	56	113	293	0	-5	-5	0	0	10
98101512	6	11.9N	134.1E	40	0	6	77	134	184	381	15	20	30	40	55	60
98101518	7	12.0N	133.0E	45	6	59	123	171	224	425	10	20	30	40	55	55
98101600	8	12.0N	132.6E	45	35	95	120	137	182	315	10	10	15	25	35	25
98101606	9	12.1N	132.4E	45	71	124	141	165	237	375	5	5	10	25	35	25
98101612	10	12.1N	132.1E	45	37	50	59	123	211	365	5	5	15	25	30	25
98101618	11	12.2N	131.8E	45	18	13	13	48	159	341	15	15	25	30	25	15
98101700	12	12.2N	131.4E	45	16	56	80	112	150	184	0	5	10	10	0	-35
98101706	13	12.1N	131.0E	45	13	31	86	148	214	274	0	10	15	10	0	-45
98101712	14	12.1N	130.5E	40	8	38	105	185	257	268	5	10	10	-5	0	-55
98101718	15	12.0N	130.2E	40	21	85	143	198	248	258	10	10	5	-5	-10	-55
98101800	16	11.8N	130.1E	40	42	93	153	195	213	210	0	0	-15	-5	-45	-55
98101806	17	11.6N	130.0E	40	37	72	97	123	120	168	0	-5	-15	-15	-55	-50
98101812	18	11.3N	129.9E	45	18	35	51	46	37	68	-5	-20	-15	-55	-65	-50
98101818	19	11.1N	129.8E	50	23	30	27	6	19	21	0	-10	-15	-60	-65	-40
98101900	20	11.0N	129.7E	65	34	43	59	86	91	113	0	10	-30	-40	-25	0
98101906	21	10.9N	129.5E	65	21	30	55	83	89	46	0	0	-40	-35	-20	25
98101912	22	10.9N	129.3E	65	18	67	131	168	172	99	0	-40	-50	-35	-20	0
98101918	23	11.0N	128.9E	75	8	59	102	114	92	42	0	-35	-40	-25	-10	20
98102000	24	11.3N	128.3E	115	5	8	32	54	58	110	0	-5	5	20	55	75
98102006	25	11.7N	127.7E	125	8	8	13	38	45	94	0	-5	10	30	70	10
98102012	26	12.2N	127.1E	135	5	23	35	38	38	75	0	10	20	45	25	0
98102018	27	12.7N	126.4E	135	0	23	31	25	31	73	0	15	30	60	45	0
98102100	28	13.0N	125.6E	135	0	8	18	29	19	11	0	-10	10	-15	-5	20
98102106	29	13.4N	124.9E	130	6	36	45	38	30	37	5	0	25	-5	0	20
98102112	30	13.7N	124.2E	130	5	13	6	37	46	29	0	15	0	5	0	20
98102118	31	13.9N	123.6E	120	8	30	30	19	26	63	0	20	5	0	5	15

Statistics for JTWC on STY 20W Babs

98102200	32	14.2N	123.1E	105	13	27	64	76	68	60	0	-35	-20	-25	-15	-5
98102206	33	14.6N	122.6E	90	5	0	50	41	39	21	0	-20	-15	-25	-15	-5
98102212	34	15.0N	122.0E	115	0	60	86	81	65	31	0	10	0	0	10	15
98102218	35	15.4N	121.3E	95	5	63	77	86	62	56	0	0	0	0	10	20
98102300	36	16.0N	120.3E	85	17	37	58	51	52	45	0	10	10	0	-5	-5
98102306	37	16.4N	119.5E	80	16	57	36	33	34	66	-5	5	10	0	-5	-5
98102312	38	16.5N	118.9E	80	12	32	13	29	41	97	0	5	10	5	-5	-5
98102318	39	16.6N	118.3E	80	50	65	76	68	69	90	0	5	10	5	0	-5
98102400	40	16.8N	117.7E	80	18	44	67	102	124	153	0	0	5	0	0	5
98102406	41	17.6N	117.2E	80	6	27	48	77	112	175	0	0	5	5	0	10
98102412	42	18.0N	116.9E	80	12	13	36	82	133	236	0	5	5	10	0	25
98102418	43	18.5N	116.5E	80	0	32	80	133	172	273	0	5	5	5	0	30
98102500	44	19.0N	116.3E	75	18	57	109	160	202		0	0	10	5	15	
98102506	45	19.6N	116.3E	75	25	66	125	169	218		0	5	10	5	20	
98102512	46	20.2N	116.3E	75	34	78	117	149	175		0	10	5	0	5	
98102518	47	20.8N	116.4E	70	22	64	83	99	109		5	10	5	0	10	
98102600	48	21.4N	116.7E	65	24	46	62	88			0	0	15	15		
98102606	49	22.0N	117.0E	65	16	18	33	49			0	0	15	25		
98102612	50	22.5N	117.2E	65	21	64	69				10	15	20			
98102618	51	22.9N	117.5E	65	40	75	112				0	10	20			
98102700	52	23.3N	117.8E	50	37	45					0	10				
98102706	53	23.9N	118.2E	45	20	16					0	10				
98102712	54	24.3N	118.6E	30	0						0					
98102718	55	24.7N	119.0E	25	0						0					
			AVERAGE		19	44	68	92	120	173	2	9	14	17	19	23
			BIAS								2	2	3	2	3	4
			# CASES		55	53	51	49	47	43	55	53	51	49	47	43

Statistics for JTWC on TS 21W Chip

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98111018		9.4N	115.6E	20												
98111100		9.3N	115.1E	25												
98111106		9.3N	114.5E	30												
98111112		9.2N	114.0E	30												
98111118		9.2N	113.5E	30												
98111200	1	9.2N	112.9E	30	5	19	72	90	60	32	-5	-10	-5	-10	-5	25
98111206	2	9.3N	112.4E	35	23	48	89	88	93		5	0	0	0	15	
98111212	3	9.5N	111.9E	40	18	27	48	50	97		0	5	0	5	20	
98111218	4	10.0N	111.4E	40	6	25	21	30	80		0	0	0	15	20	
98111300	5	10.6N	110.9E	40	0	6	46	95	106		0	-5	0	10	10	
98111306	6	11.0N	110.4E	45	8	38	84	120			-5	0	10	5		
98111312	7	11.2N	109.9E	50	6	42	102	128			0	0	5	0		
98111318	8	11.2N	109.3E	50	11	65	119				0	0	5			
98111400	9	11.0N	108.9E	50	25	84	105				0	10	10			
98111406	10	10.7N	108.6E	40	13	21					5	10				
98111412	11	10.4N	108.3E	30	5	26					-5	0				

Statistics for JTWC on TS 21W Chip

98111418	12	10.3N	107.9E	30	6						-5					
98111500	13	10.3N	107.5E	25	0						0					
			AVERAGE		10	36	76	86	87	32	2	4	4	6	14	25
			BIAS								-1	1	3	4	12	25
			# CASES		13	11	9	7	5	1	13	11	9	7	5	1

Statistics for JTWC on TS 22W Dawn

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98111618		9.6N	116.8E	20												
98111700		9.6N	116.0E	20												
98111706		9.6N	115.1E	20												
98111712		9.6N	114.3E	20												
98111718		9.8N	113.6E	20												
98111800		10.0N	113.0E	20												
98111806	1	10.3N	112.5E	25	34	77	127	151	186		0	-5	-10	5	10	
98111812	2	10.7N	112.1E	30	5	21	49	79	118		-5	-10	-5	10	10	
98111818	3	11.1N	111.5E	35	18	42	54	72			-5	-10	5	25		
98111900	4	11.5N	111.0E	40	13	30	51	88			-5	0	0	5		
98111906	5	11.9N	110.4E	45	16	30	64				-5	10	10			
98111912	6	12.2N	109.6E	40	0	13	82				-5	0	5			
98111918	7	12.5N	109.0E	35	8	42					0	10				
98112000	8	12.8N	108.4E	30	21	91					5	5				
98112006		13.1N	107.5E	20												
98112012		13.3N	106.4E	20												
			AVERAGE		15	43	71	98	152		4	6	6	11	10	
			BIAS								-3	0	1	11	10	
			# CASES		8	8	6	4	2		8	8	6	4	2	

Statistics for JTWC on TS 23W Elvis

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98112306		11.5N	119.1E	20												
98112312		11.6N	118.6E	20												
98112318		11.8N	117.9E	20												
98112400	1	12.1N	117.1E	25	5	48	136	155	163		0	-10	-15	-10	0	
98112406	2	12.4N	116.1E	25	68	147	205	220	218		0	-10	-10	-5	15	
98112412	3	12.6N	115.1E	35	39	69	59	75	96		-5	-10	-5	5	15	
98112418	4	12.9N	113.8E	40	42	87	106	140			-10	-5	-15	-10		
98112500	5	13.0N	112.5E	45	48	89	151				0	-5	-15			
98112506	6	13.2N	111.5E	45	13	31	60				0	-10	-5			
98112512	7	13.4N	110.7E	45	11	42	62				0	-5	5			
98112518	8	13.7N	109.8E	45	5	21					0	5				
98112600	9	14.0N	109.1E	40	11	31					5	15				
98112606	10	14.2N	108.4E	30	18						10					

Statistics for JTWC on TS 23W Elvis

98112612		14.4N	107.6E	20												
			AVERAGE		27	63	111	148	159		3	8	10	8	10	
			BIAS								0	-4	-9	-5	10	
			# CASES		10	9	7	4	3		10	9	7	4	3	

Statistics for JTWC on TY 24W Faith

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98120718		6.1N	141.0E	20												
98120800		6.3N	139.9E	20												
98120806	1	6.7N	138.8E	25	43	126	236	307	367	496	0	5	0	-5	-25	-40
98120812	2	7.3N	137.7E	25	68	183	308	399	496	631	0	-5	0	-15	-20	-35
98120818	3	8.1N	136.5E	25	84	211	313	425	536	703	0	-5	-10	-25	-20	-35
98120900	4	9.1N	135.1E	30	17	8	38	65	106	170	0	0	-15	-25	-30	-45
98120906	5	9.9N	133.6E	30	24	83	134	122	156	145	0	-10	-25	-25	-35	-45
98120912	6	10.6N	132.1E	30	47	133	221	297	348	363	0	-15	-25	-30	-35	-45
98120918	7	10.9N	130.6E	40	5	64	95	135	160	194	-5	-20	-15	-25	-35	-20
98121000	8	11.2N	128.8E	50	5	19	38	91	112	112	5	0	-15	-25	-15	5
98121006	9	11.2N	127.0E	60	0	90	124	147	158	86	-5	0	-20	-25	-15	10
98121012	10	12.0N	125.4E	65	8	78	143	193	219	124	0	-15	-30	-25	-15	15
98121018	11	12.2N	123.7E	65	11	76	131	169	162	212	0	-15	-20	-15	0	-15
98121100	12	12.2N	121.9E	75	11	72	115	157	218	200	-10	-20	-15	-10	0	-25
98121106	13	11.8N	120.3E	80	0	55	114	201	273	159	-5	-10	0	10	-35	-10
98121112	14	11.3N	118.8E	90	8	24	13	94	213	223	0	10	20	35	15	5
98121118	15	11.2N	117.2E	90	24	80	66	60	194	264	0	10	25	40	25	15
98121200	16	10.9N	115.8E	90	18	40	116	200	230		0	5	15	-15	-25	
98121206	17	10.6N	114.4E	90	23	73	157	204	265		0	10	20	35	35	
98121212	18	10.6N	113.3E	90	26	86	178	249	319		0	0	0	-5	20	
98121218	19	10.6N	112.5E	85	71	208	306	390	459		5	5	0	10	40	
98121300	20	10.7N	112.0E	85	31	89	162	240			5	10	15	25		
98121306	21	11.0N	111.5E	80	11	54	140	239			0	5	20	30		
98121312	22	11.4N	110.9E	75	18	76	168				5	10	35			
98121318	23	11.9N	110.2E	65	6	67	146				0	15	25			
98121400	24	12.7N	109.4E	60	8	85					0	0				
98121406	25	13.5N	108.4E	45	0	85					10	5				
98121412	26	14.3N	107.3E	30	13						5					
98121418		15.1N	106.2E	20												
			AVERAGE		23	87	151	209	263	272	2	8	16	22	23	24
			BIAS								0	-1	-1	-4	-9	-18
			# CASES		26	25	23	21	19	15	26	25	23	21	19	15

Statistics for JTWC on TS 25W Gil

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98120812		7.6N	113.9E	20												

Statistics for JTWC on TS 25W Gil

98120818		7.6N	112.8E	20												
98120900		7.5N	111.6E	25												
98120906		7.5N	110.6E	25												
98120912	1	7.6N	109.5E	25	29	64	90	77	78	122	0	-5	0	0	5	15
98120918	2	7.8N	108.6E	30	19	34	42	86	125	261	0	5	5	10	15	30
98121000	3	8.0N	107.9E	30	58	108	178	221	207	293	0	5	5	10	10	30
98121006	4	8.1N	107.2E	30	43	47	70	83	117		0	0	5	10	10	
98121012	5	8.1N	106.3E	30	47	88	111	148	213		0	-5	0	5	10	
98121018	6	8.1N	105.7E	35	43	40	80	131	137		-5	-5	0	5	20	
98121100	7	8.2N	105.1E	35	23	60	118	157	121		0	0	-5	0	5	
98121106	8	8.3N	104.4E	35	11	54	120	137			-5	-5	-10	0		
98121112	9	8.4N	103.6E	35	18	73	127	111			-5	-10	-5	0		
98121118	10	8.4N	102.7E	35	37	98	118				-5	-10	0			
98121200	11	8.3N	101.8E	35	38	80	162				-5	-5	-5			
98121206	12	8.0N	100.9E	35	45	89					-5	0				
98121212	13	7.8N	100.3E	30	18	94					0	5				
98121218	14	7.8N	99.9E	25	0						0					
98121300	15	8.0N	99.8E	20	0						0					
			AVERAGE		29	71	110	128	143	225	2	5	4	4	11	25
			BIAS								-2	-2	-1	4	11	25
			# CASES		15	13	11	9	7	3	15	13	11	9	7	3

Statistics for JTWC on TD 26W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98121700		10.9N	125.0E	20												
98121706		11.6N	123.9E	20												
98121712	1	12.5N	122.9E	25	39	119	214	346			0	0	5	15		
98121718	2	13.4N	122.1E	25 1	09	238	366				0	0	5			
98121800	3	14.5N	121.5E	25	18	75	153				0	0	5			
98121806	4	15.4N	121.1E	25	24	73					0	5				
98121812	5	16.3N	120.7E	25	66	35					0	5				
98121818	6	17.5N	120.3E	25	31						0					
98121900	7	18.7N	119.8E	20	29						0					
			AVERAGE		45	108	244	346			0	2	5	15		
			BIAS								0	2	5	15		
			# CASES		7	5	3	1			7	5	3	1		

Statistics for JTWC on TD 27W

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98121818		12.9N	113.1E	20												
98121900		13.2N	113.2E	20												
98121906	1	13.5N	113.3E	30	31	79	181	286	355		0	0	5	5	15	
98121912	2	13.9N	113.4E	30	46	120	219	301	358		0	0	5	10	15	

Statistics for JTWC on TD 27W

98121918	3	14.5N	113.6E	30	42	130	225	298	375		0	0	5	10	15	
98122000	4	15.4N	113.9E	30	8	63	112	159	229		0	0	10	10	20	
98122006	5	16.3N	114.2E	30	24	101	138	167			0	0	5	5		
98122012	6	17.1N	114.6E	30	18	63	125	209			0	5	0	0		
98122100	7	18.4N	115.3E	25	11	24	72				0	0	5			
98122106	8	18.8N	115.7E	25	6	26					0	0				
98122112	9	19.1N	116.1E	25	17	45					0	5				
98122118	10	19.4N	116.6E	25	30						0					
98122200	11	19.7N	117.2E	20	33						5					
			AVERAGE		25	72	153	237	329		0	1	5	7	16	
			BIAS								0	1	5	7	16	
			# CASES		11	9	7	6	4		11	9	7	6	4	

Statistics for JTWC on TC 01B

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98051300		4.0N	85.5E	15												
98051306		5.2N	86.0E	20												
98051312		6.2N	86.4E	20												
98051318		7.3N	86.7E	20												
98051400		8.2N	86.6E	20												
98051406		8.9N	86.1E	20												
98051412		9.3N	85.3E	20												
98051418		9.4N	84.4E	20												
98051500		9.5N	83.6E	20												
98051506		9.7N	82.5E	20												
98051512		9.9N	81.5E	20												
98051518		10.1N	80.6E	25												
98051600		10.5N	80.3E	25												
98051606		11.0N	80.5E	25												
98051612		11.4N	81.9E	25												
98051618		12.2N	83.6E	25												
98051700		12.9N	85.0E	25												
98051706		13.6N	86.3E	25												
98051712		14.1N	87.1E	25												
98051718		14.5N	87.7E	25												
98051800		15.1N	88.4E	25												
98051806	1	15.9N	88.9E	30	24	90	156	156	150		0	-5	-5	-10	-5	
98051812	2	17.0N	89.3E	30	17	27	48	54	151		0	-10	-10	-15	25	
98051818	3	18.0N	89.6E	35	17	42	32	65	179		0	-10	-15	-5	40	
98051900	4	19.1N	90.0E	40	22	8	38	78			0	-5	-10	-5		
98051906	5	20.2N	90.4E	45	6	41	94	178			0	-10	-5	5		
98051912	6	20.9N	90.8E	55	22	66	126				0	-10	15			
98051918	7	21.3N	91.1E	60	33	78	170				-5	0	30			
98052000	8	21.9N	91.5E	70	8	87					-5	25				
98052006	9	22.5N	92.0E	60	6	68					5	20				
98052012	10	23.8N	92.9E	40	0						0					

Statistics for JTWC on TC 01B

98052018	11	24.3N	93.8E	25	0						0					
			AVERAGE		14	56	95	106	160		1	11	13	8	23	
			BIAS								0	-1	0	-6	20	
			# CASES		11	9	7	5	3		11	9	7	5	3	

Statistics for JTWC on TC 02A

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98052706		11.2N	61.4E	30												
98052712		11.9N	60.9E	30												
98052718		12.5N	60.6E	30												
98052800	1	12.8N	60.4E	35 1	21	153	195				0	0	-5			
98052806	2	13.4N	59.7E	35	37	84					0	5				
98052812	3	13.6N	59.3E	35	59	72					0	-5				
98052818	4	13.9N	59.1E	30	42						0					
98052900	5	14.3N	59.0E	30	0						0					
			AVERAGE		52	103	195				0	3	5			
			BIAS								0	0	-5			
			# CASES		5	3	1				5	3	1			

Statistics for JTWC on TC 03A

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98060106		10.6N	74.7E	25												
98060112		10.7N	74.4E	30												
98060118		10.7N	74.2E	35												
98060200		10.8N	73.9E	35												
98060206		10.8N	73.7E	35												
98060212		10.8N	73.4E	35												
98060218		10.8N	73.0E	35												
98060300		10.9N	72.7E	35												
98060306		11.0N	72.3E	35												
98060312		11.0N	72.0E	30												
98060318		11.1N	71.8E	30												
98060400	1	11.2N	71.6E	30	93	110	137	130	129	159	0	5	5	-5	-5	-25
98060406	2	11.3N	71.4E	30 1	11	159	194	227	235	381	0	5	-5	-15	-40	-45
98060412	3	11.4N	71.2E	30	13	29					-5	-10				
98060500	4	11.6N	70.8E	35	34	89	118	159	226	341	-5	-15	-20	-35	-40	-60
98060506	5	11.7N	70.5E	40	35	95	124	185	228	299	-10	-15	-35	-35	-40	-65
98060512	6	11.9N	70.1E	50	5	13	66	135	217	421	0	0	-5	-5	-5	-20
98060518	7	12.0N	69.7E	50	6	27	90	157	234	434	0	-15	-5	-5	-15	-20
98060600	8	12.2N	69.5E	55	6	24	72	138	216	400	0	-15	-10	-15	-25	-35
98060606	9	12.5N	69.3E	70	21	61	96	156	235	436	0	5	5	-5	-10	15
98060612	10	13.1N	68.9E	70	18	46	88	134	180	320	0	0	0	-10	-5	40

Statistics for JTWC on TC 03A

98060618	11	13.7N	68.5E	70	5	0	18	42	66		0	-5	-15	-20	-10	
98060700	12	14.3N	68.2E	75	11	37	57	71	115		0	-5	-20	-15	-20	
98060706	13	15.0N	67.9E	75	8	34	79	111	192		0	-15	-25	-15	5	
98060712	14	15.8N	67.7E	80	26	17	19	66	158		0	-15	-15	-25	25	
98060718	15	16.6N	67.7E	90	11	25	48	121			-10	-20	-15	0		
98060800	16	17.6N	67.7E	95	16	42	94	213			-5	0	-5	40		
98060806	17	18.6N	67.7E	100	0	34	113				0	5	10			
98060812	18	19.6N	67.8E	95	8	64	116				0	-10	30			
98060818	19	20.5N	68.2E	95	11	41					0	10				
98060900	20	21.5N	69.0E	105	18	97					-15	0				
98060906	21	22.8N	69.9E	80	16						0					
98060912	22	24.0N	70.9E	60	0						0					
			AVERAGE		22	52	90	136	187	355	2	9	13	16	19	36
			BIAS								-2	-6	-7	-11	-14	-24
			# CASES		22	20	17	15	13	9	22	20	17	15	13	9

Statistics for JTWC on TC 04A

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98092818		18.4N	67.7E	25												
98092900		18.4N	67.5E	25												
98092906		18.4N	67.3E	25												
98092912		18.3N	66.8E	25												
98092918		18.2N	66.4E	30												
98093000	1	18.2N	65.7E	35	0	29	39				0	0	0			
98093012	2	18.1N	64.2E	35	29	67					0	0				
98100100	3	17.7N	63.2E	30	0						0					
			AVERAGE		10	48	39				0	0	0			
			BIAS								0	0	0			
			# CASES		3	2	1				3	2	1			

Statistics for JTWC on TC 05A

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98101500		17.1N	62.2E	20												
98101506		17.1N	63.0E	25												
98101512		17.1N	63.8E	25												
98101518		17.0N	64.8E	25												
98101600	1	17.2N	65.7E	35	13	95	160	184	206		0	5	10	20	30	
98101612	2	18.4N	68.5E	35	8	85	134	135			0	0	10	15		
98101700	3	20.2N	69.3E	35	12	66	111				0	0	0			
98101712	4	21.1N	69.7E	30	0	28					0	5				
98101800	5	21.8N	70.7E	25	0						0					
			AVERAGE		7	68	135	160	206		0	3	7	18	30	
			BIAS								0	3	7	18	30	

Statistics for JTWC on TC 05A

			# CASES		5	4	3	2	1		5	4	3	2	1	

Statistics for JTWC on TC 06B

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98111300		11.4N	87.3E	20												
98111306		11.7N	87.5E	25												
98111312		12.1N	87.4E	25												
98111318		12.6N	87.0E	30												
98111400	1	13.3N	86.5E	40	43	152	208	304	536		-5	-25	-25	-35	5	
98111406	2	14.4N	85.8E	55	13	24	53	85			0	-10	-5	-25		
98111412	3	15.1N	85.1E	65	24	92	84	115			0	5	-20	-5		
98111500	4	16.1N	83.9E	70	0	51	259				0	-15	15			
98111512	5	17.8N	82.7E	85	18	216					0	20				
98111600	6	22.2N	82.1E	50	0						0					
			AVERAGE		17	107	151	168	536		1	15	16	22	5	
			BIAS								-1	-5	-9	-22	5	
			# CASES		6	5	4	3	1		6	5	4	3	1	

Statistics for JTWC on TC 07B

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98111600		10.1N	102.3E	25												
98111606		10.2N	101.3E	25												
98111612		10.2N	100.6E	25												
98111618		10.3N	99.9E	25												
98111700		10.3N	99.0E	25												
98111706		10.4N	98.0E	25												
98111712		10.4N	97.2E	25												
98111718		10.4N	96.4E	25												
98111800		10.4N	95.5E	25												
98111806		10.5N	94.7E	25												
98111812		10.6N	94.1E	25												
98111818		11.0N	93.4E	25												
98111900		11.4N	92.9E	25												
98111906		11.9N	92.2E	25												
98111912		12.5N	91.3E	25												
98111918		13.2N	90.2E	25												
98112000	1	14.0N	89.0E	35	58	81	83	130	148		0	-10	0	0	0	
98112006	2	14.9N	88.2E	55	37	160	235	273	324		-10	10	5	-10	-15	
98112012	3	15.7N	87.9E	55	23	71	77	123	135		0	10	0	-20	0	
98112100	4	16.8N	87.6E	55	13	80	83	169	316		0	-5	-10	25	15	
98112112	5	18.7N	87.2E	65	29	74	157	280			0	-5	10	0		
98112200	6	19.7N	87.7E	75	39	73	139				0	35	15			
98112206	7	20.3N	88.1E	55	29	160					0	10				

Statistics for JTWC on TC 07B

98112212	8	21.2N	89.0E	40	53	167					0	0				
98112300	9	22.8N	91.1E	35	0						0					
			AVERAGE		32	108	129	195	231		1	11	7	11	8	
			BIAS								-1	6	3	-1	0	
			# CASES		9	8	6	5	4		9	8	6	5	4	

Statistics for JTWC on TC 08A

	WN	BEST TRACK			POSITION ERRORS						WIND ERRORS					
DTG	NO.	LAT	LONG	wind	00	12	24	36	48	72	00	12	24	36	48	72
98121118		10.3N	71.9E	20												
98121200		10.3N	70.8E	25												
98121206		10.3N	69.9E	25												
98121212		10.3N	69.3E	25												
98121218		10.4N	68.9E	30												
98121300	1	10.5N	68.6E	35	21	60	141	240	346	318	0	-5	-10	-5	5	35
98121306	2	10.8N	68.1E	45	18	24	48	150	214	216	0	5	5	15	20	55
98121312	3	11.1N	67.6E	45	8	45	105	198	239	200	0	0	5	15	20	55
98121318	4	11.6N	67.3E	50	13	63	157	213	219	193	0	-5	5	10	20	55
98121400	5	12.3N	67.2E	55	5	13	86	121	118	81	0	0	5	10	40	60
98121406	6	13.0N	67.0E	60	13	59	96	99	77	42	0	10	10	15	45	60
98121412	7	14.0N	66.8E	60	36	114	110	103	67	116	0	5	10	35	45	55
98121418	8	15.3N	66.5E	60	0	42	85	109	120	90	0	0	5	35	40	50
98121500	9	16.2N	66.1E	60	21	17	69	121	160		0	0	25	35	45	
98121506	10	16.8N	65.8E	65	17	12	64	127	159		0	5	25	20	10	
98121512	11	17.1N	65.5E	65	11	86	132	184	209		0	20	25	25	15	
98121518	12	17.5N	64.5E	65	0	40	82	95	92		0	25	20	10	10	
98121600	13	18.0N	63.5E	45	18	83	111	96			0	-5	-5	-5		
98121606	14	18.0N	62.4E	40	68	144	182	158			0	-5	-5	0		
98121612	15	18.0N	61.3E	40	17	40	93				0	5	5			
98121618	16	18.1N	60.0E	40	8	13	68				0	0	0			
98121700	17	18.3N	58.8E	35	5	45					0	0				
98121706	18	18.7N	57.4E	35	6	67					0	0				
98121712	19	19.5N	56.3E	30	0						0					
98121718		20.4N	55.5E	25												
			AVERAGE		15	54	102	144	168	157	0	5	10	17	26	53
			BIAS								0	3	8	15	26	53
			# CASES		19	18	16	14	12	8	19	18	16	14	12	8

Chapter 7
Tropical Cyclone Support Summary

7.1 INTRODUCTION

This chapter of the 1998 Annual Tropical Cyclone Report is provided to inform the reader on some of the support that is provided to JTWC. This summary is by no means the total support provided to this organization, but reflects the major ongoing efforts.

7.2 SYSTEMATIC APPROACH TO TROPICAL CYCLONE FORE-SACTING

L. E. Carr III and R. L. Elsberry Naval Postgraduate School, Monterey, CA 93943

The Systematic Approach to Tropical Cyclone Track Forecasting (Systematic Approach) is a project initiated in 1994 to assist forecasters in making optimum use of available numerical models and other objective techniques when formulating the official track forecast. During the last year, a preliminary Model Traits Knowledge Base has been developed based on the detailed analysis of all highly erroneous NOGAPS and GFDN track forecasts of western North Pacific TCs during 1997. Key features of this knowledge base are: (i) the identification four error mechanisms that frequently degrade NOGAPS forecasts only, one error mechanism that frequently degrades GFDN forecasts only, and two error mechanisms that frequently degrade NOGAPS and GFDN forecasts simultaneously; (ii) identification of key indicators in the numerical model forecast fields for each of the frequently recurring error mechanisms; and (iii) thorough documentation of each frequently recurring error mechanism that includes illustrative case studies. With this knowledge base, the forecaster can identify model track forecasts that may be highly degraded, and which should either be excluded or given low weight when formulating the official track forecast.

Research was also conducted into applying ensemble prediction concepts to formulate a selective consensus from the subset of numerical model tracks to be identified by the forecaster via the Model Traits Knowledge Base described above. This research extends that of J. Goerss (Naval Research Laboratory- Monterey), who has developed a simple, economical (free) consensus of up to three global model or two regional model forecast tracks, by using all five numerical model tracks normally available to JTWC. This extension of the Goerss technique will provide a tool to assist the forecaster in comparing the model tracks and assessing whether a particular track is good, and thus should be included in the consensus, or degraded and thus should be discarded. Features of the ensemble approach that are useful to the forecaster include cluster recognition, cluster membership analysis, and determination of the overall spread of the ensemble.

Development has continued on a Systematic Approach Expert System (SAES) prototype that is to undergo a preliminary field evaluation during the 1999 western North Pacific season. The SAES employs sophisticated field and forecast track displays, and incorporates key aspects of the Model Traits Knowledge Base and ensemble analysis concepts described above. Key features of the SAES include: a systematic logic for presenting information that a forecaster needs to evaluate the present synoptic situation to assess the likely quality of the dynamical or other objective guidance, a computation of the consensus track of selected numerical models, and a recording of the forecaster's prognostic reasoning for accepting or rejecting certain numerical model forecasts that can be used as guidance by the next forecaster.

7.3 TROPICAL CYCLONE SUPPORT SUMMARY FOR ATCF

The Automated Tropical Cyclone Forecasting System Version 3.3 C. R. Sampson, A. J. Schrader, M. D. Frost, and D. H. Grant Naval Research Laboratory, Monterey, CA 93943

The UNIX version of the Automated Tropical Cyclone Forecasting System (ATCF) has been used successfully at JTWC since 1996. This year, system support was extensive and included moving all ATCF related equipment out of Guam and into the new JTWC at NPMOC Pearl Harbor and the new AJTWC at NPMOC Yokosuka. This was done in addition to developing a new version of ATCF. ATCF 3.3 was installed at JTWC for the 1999 season and includes the following improvements:

1) A Y2K compliant database and software, 2) Extended forecast periods that include 96- and 120-hours, 3) Scatterometer and cloud tracked wind display, 4) Toggles switches for land fill and geographic labels, 5) Edit templates for fix and track data, 6) Automated recall of previously saved window states, 7) A new Tactical Environmental Data Server (TEDS) - Version4.x, 8) A NOGAPS vortex tracker (NGPR) that runs on the ATCF, 9) A scripting language for generation of ATCF graphic files and 10) An automated dissemination of the warnings to Joint Metoc Viewer (JMV).

The next ATCF upgrade, ATCF 3.4, will focus on developing ways of integrating satellite imagery in the ATCF display and improving tropical cyclone data transfers between National Oceanographic and Atmospheric Administration and U.S Military forecast centers.

7.4 SSM/I TROPICAL CYCLONE STRUCTURE AND INTENSITY

Jeff Hawkins, Richard Bankert, and Paul Tag, Naval Research Laboratory, Monterey Juanita Chase, Naval Research Laboratory, Stennis Space Center Marla Helveston, Analysis & Technology

The Special Sensor Microwave/Imager (SSM/I) has a suite of passive microwave channels that enable it to penetrate non-raining clouds and map out tropical cyclone (TC) associated rain and moisture structure. This ability to detect rainbands, eyewall(s) and eye/center locations can significantly assist the analyst and Typhoon Duty Officer (TDO) when upper-level clouds obscure geostationary and/or polar orbiter visible and infrared (vis/IR) imagery. TC structure valuable for positioning and understanding storm intensity and intensity trends can then be used to upgrade the confidence and accuracy of storm warnings/advisories.

The Naval Research Laboratory's Marine Meteorology Division in Monterey, CA (NRL-MRY) has been exploring ways to extract additional information from the wealth of information contained in TC SSM/I imagery (Hawkins, et. al., 1998a, b). The main focus has been aimed at the high resolution (12-15 km) 85 GHz channels that nicely map TC structure and readily depict storm rainbands, eyewall(s) and center locations. This has been done by processing over 2,300 SSM/I passes coincident with TCs ranging in strength from tropical disturbances to super typhoons and CAT 5 hurricanes.

Numerous instances occurred during the 1998 season when SSM/I imagery was used to accurately view storm structure when not possible with vis/IR imagery. JTWC warning discussions now routinely mention passive microwave data when this valuable data set is incorporated as part of the satellite reconnaissance mission. During the end of the 1998 season, passive microwave data from the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) began being posted by NRL-MRY for storms within the JTWC domain. The TMI is very similar to the more familiar SSM/I sensor, but has more than twice the spatial resolution since it is flying at half the SSM/I's altitude. Therefore, the 5-km 85 GHz images from the TMI can resolve features in tropical cyclones not previously seen with SSM/I data (Hawkins, et. al., 1999). Near real-time examples of both data sets can be seen on the NRL-MRY tropical cyclone web page: http://www.nrlmry.navy.mil/sat_products.html.

Two efforts have been studied to extract TC intensities from automated analyses of SSM/I digital data. The first effort involves a neural network method which; 1) uses 85 GHz, H-polarization brightness temperatures, 2) represents the patterns in the 85 GHz images via its Empirical Orthogonal Functions (EOF), 3) trains the neural net with the EOFs most highly correlated with intensity, and 4) trains the net with a dependent storm data base using JTWC/NHC best track intensities. The database now contains ¿ 1,100 TCs in the dependent data set and verification using "independent". Application to "independent" data sets such as for Super Typhoon Keith indicate the method has skill in matching the best track intensity trends, though has difficulty with rapid intensification. Techniques for using the intensity from previous images (similar to the Dvorak method) are undergoing tests.

The second effort utilizes computer vision capabilities to analyze both 85 GHz and rainrate products from the SSM/I. Spectral, spatial and textural measures were developed to extract features that are most highly correlated with TC intensity. Some of these features are analogous to those used within the Dvorak method, such as banding of particular temperature ranges, minimum brightness temperature, rainrates above a certain threshold, etc. Results to date indicate an RMS nearing 15 m/s, the likely accuracy of the best track data set. Evaluation of this method on Keith indicates significant skill in not only catching the intensity trends, but also in mirroring the best track fluctuations during the long-lived course of this storm's lifespan. Both methods are currently being retrained on a larger data set and will undergo a demonstration phase during the 1999 season.

APPENDIX A - DEFINITIONS

Alternate Joint Typhoon Warning Center (AJTWC): Naval Pacific Meteorology and Oceanography Center, Yokosuka, Japan.

Center: The axis or pivot of a tropical cyclone usually determined by wind, temperature or pressure distribution.

Center Fix: Location of the center of a tropical cyclone by means other than reconnaissance aircraft penetration (e.g., AIREPS, aircraft/ship/land-based radar, or weather satellite). See Vortex Fix, below.

Central Pacific Hurricane Center (CPHC): The NWS Forecast Office responsible for issuing tropical cyclone warnings north of the equator between 180 degrees and 140 degrees west. CPHC is located at the Honolulu National Weather Service Forecast Office.

Checksum: Least significant digit of the numerical sum in a sequence of digits. Used in fix data and tropical cyclone warning messages wherever latitude, longitude, and time are given.

Cyclone: A closed atmospheric circulation rotating about an area of low pressure (counterclockwise in the Northern Hemisphere).

Extrapolated Warning Position: A forecast warning position derived from the previous warning position when no reliable fix information has been received since last warning.

Extratropical: Used in warnings and tropical summaries to indicate a cyclone has lost "tropical" characteristics. (NOTE: Draw no inference concerning the intensity or areal extent of a cyclone from this change to extratropical status, as a cyclone may become extratropical without losing winds of typhoon or storm intensity.) Commands concerned must not relax vigilance when a tropical cyclone is reclassified as extratropical. Warning activities will issue subsequent warnings as required.

Eye: Central area of a tropical cyclone when more than half is surrounded by a wall cloud.

Gusts: Rapid fluctuations in wind speed with a variation of 10 knots (5m/s) or more between peaks and lulls.

Hurricane: See "Typhoon/Hurricane", below.

Intensity: Maximum sustained surface wind speed, typically within one degree of the center of a tropical cyclone. U.S. warnings base sustained winds on a 1-minute average of the wind speed, while the warnings of many other nations base sustained winds on a 10-minute average. This use of a different time base results in sustained winds on foreign warnings being 12 percent lower than those of U.S. warnings

Joint Typhoon Warning Center (JTWC): A joint USN/USAF organization under the command of Commanding Officer, Naval Pacific Meteorology and Oceanography Center Pearl Harbor, Hawaii and the directorship of the Detachment 1, PACAF Air Operations Squadron (DET 1, PACAF AOS) Commander. CINCPACFLT established it on 1 May 1959 by direction of USCINCPAC. JTWC issues tropical cyclone warnings for the USPACOM area west of 180 degrees to the east coast of Africa.

Maximum Sustained Wind: Highest surface wind speed of a cyclone averaged over a 1-minute period of time. (NOTE: Wind is subject to gusts which bring a sudden, temporary increase in speed, e.g. MAXIMUM SUSTAINED WIND speeds of 30 knots may have superimposed gusts of 40 knots.) (See "INTENSITY").

Monsoon Depression: A tropical cyclonic vortex characterized by:

a. Its large size, the outer-most closed isobar may have a diameter on the order of 600NM (1000 km).

b. A loosely organized cluster of deep convective elements.

c. A low-level wind distribution which features a light-wind core which may be partially surrounded by a band of gales.

d. A lack of a distinct cloud system center. Note, most monsoon depressions in the western North Pacific eventually acquire persistent central convection and accelerated core winds leading to its transition into a convectional tropical cyclone.

Monsoon Gyre: A mode of the summer monsoon circulation of the western North Pacific characterized by:

a. A very large, nearly circular low-level cyclonic vortex that has an outer-most closed isobar with diameter on the order of 1200 nm (2500 km).

b. A cloud band rimming the southern through eastern periphery of the vortex/surface low.

c. A relatively long (two-week) life span - initially, a subsident regime exists in its core and western and northwestern quadrants with light winds and scattered low cumulus clouds; later, the area within the outer closed isobar may fill with deep convective clouds and become a monsoon depression or tropical cyclone.

d. The large vortex cannot be the result of the expanding wind field of a preexisting monsoon depression or tropical cyclone. Note, a series of small or very small tropical cyclones may emerge from the "head" or leading edge of the peripheral cloud band of a monsoon gyre (Lander, 1993).

Monsoon Trough: A low latitude low-pressure region occurring near large continental areas due to land-sea monsoonal effects. A directional shear zone with westerlies on the equatorial side and easterlies on the polar side characterize the trough.

Movement Past 6 Hours: Estimated movement of a tropical cyclone at warning-time. It is based on apparent motion of the cyclone between warning time and six hours prior. This estimate does not reflect short-term, small-scale oscillations of the cyclone center.

National Hurricane Center (NHC): NWS Forecast Office responsible for issuing tropical cyclone warnings in the Pacific area of the Northern Hemisphere east of 140 degrees west. NHC is located in Miami, FL.

National Hurricane Operations Plan (NHOP): A Working Group for Hurricane and Winter Storm Operations of the Office of the Federal Coordinator for Meteorological Services and Supporting Research publishes the NHOP annually in coordination with the Departments of Defense, Transportation, and Commerce. The NHOP serves the same purpose as the USCINCPACINST 3140.1 (series) for the Atlantic and North Pacific Ocean east of 180 degrees. Whenever possible, details of this instruction coincide with those of the NHOP.

Prognostic Reasoning Message: This message with the internal caveat "FOR METEOROLOGISTS" contains a technical discussion of current synoptic conditions and reasoning for the forecast track, intensity, and wind distribution in the most recent tropical cyclone warning.

Quadrant: The 90 degrees sector of the cyclone centered on the designated direction of an eight-point compass. (For example: "East Quadrant" refers to the sector of the cyclone from 045 degrees through 090 degrees to 135 degrees.)

Relocated: Term used in a warning to indicate a vector drawn from the preceding to current position is not necessarily a reasonable representation of cyclone movement.

Semicircle: The 180 degrees sector of a cyclone centered on a direction designated from an eight-point compass. (EXAMPLE: "South Semi-circle" refers to the segment of a cyclone from 090 degrees through 180 degrees to 270 degrees.)

Significant Tropical Cyclone: A tropical cyclone becomes "significant" with issuance of the first numbered warning by the responsible warning agency.

Significant Tropical Weather Advisory: A daily message describing significant tropical activity and JTWC's evaluation of the potential for development into a significant tropical cyclone.

Size: A real extent of the tropical cyclone, usually measured radially outward from the center to outer-most closed isobar.

Storm Surge: A sudden abnormal rise in the level of the sea associated with a tropical cyclone. This wind-induced increase in wave height can be especially dangerous when it arrives coincident with local high tide.

Storm Tide: Actual level of sea water resulting from the astronomic tide combined with the storm surge.

Strength: Average speed of surrounding low-level wind flow, usually measured within one to three degrees of the center of a tropical cyclone.

Super Typhoon/Hurricane: Warm core tropical cyclone in which the maximum sustained surface wind (1-minute mean) is 130 knots or greater.

Suspect Area: Area suspected of containing a developing or existing tropical cyclone. Suspect areas are listed in the ABIO and ABPW.

Tropical Cyclone: General term for a non-frontal low-pressure system, developing over tropical or subtropical waters, and having a definite organized circulation.

Tropical Cyclone Formation Alert: Message advising of an area with the potential for development into a significant tropical cyclone.

Tropical Cyclone Warning: Message issued by responsible forecast activities that provide tropical cyclone location, intensity, size, and movement.

Tropical Depression: Tropical cyclone that may have one or more closed isobars and maximum sustained surface winds (1-minute mean) of 33 knots or less.

Tropical Disturbance: Discrete system of apparently organized convection, generally 100 to 300 miles in diameter, that originates in the tropics or sub-tropics, and has a non-frontal migratory character and maintains its identity for 24 hours or more. A weak surface circulation may exist. If so, it may or may not be associated with a detectable perturbation of the upper-air wind field. It is the basic generic designation, which, in successive stages of intensification, becomes a tropical depression, tropical storm, or typhoon (hurricane).

Tropical Storm: A warm core tropical cyclone with maximum sustained surface winds (1-minute mean) in the range of 34 to 63 knots inclusive.

Typhoon/Hurricane: A warm core tropical cyclone in which maximum sustained surface wind (1-minute mean) ranges from 64 to 129 knots. Called a typhoon if west of 180 degrees longitude and a hurricane if east of 180 degrees. Foreign governments use these or other terms for tropical cyclones and may apply different intensity criteria.

USCINCPACINST 3140.1 (series): U.S. Pacific Command Tropical Cyclone Operations Manual.

Wall Cloud: An organized band of cumuliform clouds immediately surrounding the central area of low pressure of a tropical cyclone. Wall clouds may entirely enclose the eye or only partially surround it.

Westerly Wind Burst (WWB): A short-duration low-level westerly wind event which occurs along and near the equator in the western Pacific Ocean and sometimes in the Indian Ocean. Typically lasts several days and has westerly winds of at least 10 knots. Intense WWB's are associated with a large cluster of deep-convective clouds along the equator and is a necessary precursor to the formation of tropical cyclone twins symmetrical with respect to the equator.

APPENDIX B - TROPICAL CYCLONE NAMES

Names for tropical cyclones in the North West Pacific Ocean and South China Sea (Effective until 31 December 1999)

NOTE: Tropical cyclone names will be assigned by JTWC in rotation, alphabetically, starting with (Ann) for the first tropical cyclone of 1996. When the last name in Column 4 (Zia) has been used, the sequence will begin again with the first name in Column 1 (Ann).

This name rotation will occur through 31 December 1999.

Ann	Abel	Amber	Alex
Bart	Beth	Bing	Babs
Cam	Carlo	Cass	Chip
Dan	Dale	David	Dawn
Eve	Ernie	Ella	Elvis
Frankie	Fern	Fritz	Faith
Gloria	Greg	Ginger	Gil
Herb	Hannah	Hank	Hilda
Ian	Isa	Ivan	Iris
Joy	Jimmy	Joan	Jacob
Kirk	Kelly	Keith	Kate
Lisa	Levi	Linda	Leo
Marty	Marie	Mort	Maggie
Niki	Nestor	Nichole	Neil
Orson	Opal	Otto	Olga
Piper	Peter	Penny	Paul
Rick	Rosie	Rex	Rachel
Sally	Scott	Stella	Sam
Tom	Tina	Todd	Tanya
Violet	Victor	Vicki	Virgil
Willie	Winnie	Waldo	Wendy
Yates	Yule	Yanni	York
Zane	Zita	Zeb	Zia

NOTE: Effective 1 January, 2000, JTWC will no longer name tropical cyclones in the North West Pacific. The U.S. Department of Defense tropical cyclone designation will be a tropical cyclone number and basic designator (e.g. Typhoon 01W). After the Regional Specialized Meteorological Center, (RSMC) in Tokyo, Japan, has named a tropical cyclone, JTWC will include the name in parenthesis following the tropical cyclone number and basin designator (e.g. Typhoon 01W (Damrey). RSMC Tokyo is the World

Meteorological Organization sanctioned warning agency responsible for the North Western Pacific Ocean including the South China Sea.

Names for Western North Pacific Ocean and South China Sea Tropical cyclones (Effective 1 January, 2000)

	I	II	III	IV	V
Contributed by	Name	Name	Name	Name	Name
Cambodia	Damrey	Kong-Rey	Nakri	Krovanh	Sarika
China	Longwang	Yutu	Fengshen	Dujuan	Haima
Dpr Korea	Kirogi	Toraji	Kalmaegi	Maemi	Meari
Hk, China	Kai-Tak	Man-Yi	Fung-Wong	Choi-Wan	Ma-On
Japan	Tembin	Usagi	Kammuri	Koppu	Tokage
Lao Pdr	Bolaven	Pabuk	Phanfone	Ketsana	Nock-Ten
Macau	Chanchu	Wutip	Vongfong	Parma	Muifa
Malaysia	Jelawat	Sepat	Rusa	Melor	Merbok
Micronesia	Ewiniar	Fitow	Sinlaku	Nepartak	Nanmadol
Philippines	Bilis	Danas	Hagupit	Lupit	Talas
Ro Korea	Kaemi	Nari	Changmi	Sudal	Noru
Thailand	Prapiroon	Vipa	Megkhla	Nida	Kularb
U.S.A.	Maria	Francisco	Higos	Omais	Roke
Viet Nam	Saomai	Lekima	Bavi	Conson	Sonca
Cambodia	Bopha	Krosa	Maysak	Chanthu	Nesat
China	Wukong	Haiyan	Haishen	Dianmu	Haitang
Dpr Korea	Sonamu	Podul	Pongsona	Mindulle	Nalgae
Hk, China	Shanshan	Lingling	Yanyan	Tingting	Banyan
Japan	Yagi	Kajiki	Kujira	Kompasu	Washi
Lao Pdr	Xangsane	Faxai	Chan-Hom	Namtheun	Matsa
Macau	Bebinca	Vamei	Linfa	Malou	Sanvu
Malaysia	Rumbia	Tapah	Nangka	Meranti	Mawar
Micronesia	Soulik	Mitag	Soudelor	Rananim	Guchol
Philippines	Cimaron	Hagibis	Imbudo	Malakas	Talim
Ro Korea	Chebi	Noguri	Koni	Megi	Nabi
Thailand	Durian	Ramasoon	Hanuman	Chaba	Khanun
U.S.A.	Utor	Chataan	Etau	Kodo	Vicente
Viet Nam	Trami	Halong	Vamco	Songda	Saola

APPENDIX C - ACRONYMS

AB	Air Base
ABW	Air Base Wing
ABIO	Significant Tropical Weather Advisory for the Indian Ocean
ABPW	Significant Tropical Weather Advisory for the Western Pacific Ocean
ACCS	Air Control Center Squadron
ADEOS	Japanese Advanced Earth Observing Satellite
ADP	Automated Data Processing
AFB	Air Force Base
AFWA	Air Force Weather Agency
AIREP	Aircraft (Weather) Report
AJTWC	Alternate Joint Typhoon Warning Center, Yokosuka, Japan
AMOS	Automatic Meteorological Observing Station
AOR	Area of Responsibility
ARC	Automated Remote Collection (system)
ARGOS	International Service for Drifting Buoys
ARQ	Automated Response to Query
ATCF	Automated Tropical Cyclone Forecast (system)
ATCR	Annual Tropical Cyclone Report
AUTODIN	Automated Digital Network

AVHRR	Advanced Very High Resolution Radiometer
AWDS	Automated Weather Distribution System
AWN	Automated Weather Network
BLND	Blended (Hybrid Aid)
CDO	Central Dense Overcast
CI	Current Intensity
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CINCPACFLT	Commander-in-Chief, Pacific Fleet
CIV	Civilian
CLD	Cloud
CLIM	Climatology
CLIP or CLIPER	Climatology and Persistence Technique
CM	Centimeter(s)
C-MAN	Coastal-Marine Automated Network
CMOD	Compact Meteorological and Oceanographic Drifter (buoy)
COMNAVMETOCCOM or CNMOC	Commander, Naval Meteorology and Oceanography Command
CPA	Closest Point of Approach
CPHC	Central Pacific Hurricane Center, Honolulu, HI
CSC	Cloud System Center
CSUM	Colorado State University Model
CW	Continuous Wave
DAVE	A Hybrid Aid
DD	Digital Dvorak

DDN	Defense Data Network
DEG	Degree(s)
DISN	Defense Information Systems Network
DMS	Defense Messaging System
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
DSN	Defense Switched Network
DTG	Date Time Group
EGRR	Bracknell Model
ENSO	El Ni o-Southern Oscillation
ERS	European Remote Sensing Satellite
FBAM	FNMOC Beta and Advection Model
FI	Forecast Intensity (Dvorak)
FLENUMETOCCEN or FNMOC	Fleet Numerical Meteorology and Oceanography Center, Monterey, CA
FT	Foot/Feet
FTP	File Transfer Protocol
GFDN	Geophysical Fluid Dynamics-Navy Model
GMS	Japan Meteorological Agency Geostationary Meteorological Satellite
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
GSRS	Geostationary Satellite Receiving System
GTS	Global Telecommunications System
HIRS	High Resolution Infrared Sounder
hPa	Hectopascal

HPAC	Mean of XTRP and CLIM Techniques (Half Persistence and Climatology)
HF	High Frequency
HR	Hour(s)
ICAO	International Civil Aviation Organization
INIT	Initial
INST	Instruction
IP	Internet Protocol
IR	Infrared
JGSM	Japan Meteorological Agency Global Spectral Model
JTWC	Joint Typhoon Warning Center, Pearl Harbor, HI
JTWC92	Statistical-Dynamical or JT92 Objective Technique
JTYM	Japan Meteorological Agency Typhoon Model
KM	Kilometer(s)
KT	Knot(s)
LAN	Local Area Network
LAT	Latitude
LLCC	Low-Level Circulation Center
LONG	Longitude
LUT	Local User Terminal
LVL	Level
M	Meter(s)
MAX	Maximum
MB	Millibar(s)
MBAM	Medium Beta and Advection Model

MCAS	Marine Corps Air Station
MCS	Mesoscale Convective System
MET	Meteorological
METEOSAT	European Meteorological Satellite
MIN	Minimum
MINI-MET	Mini-Meteorological(buoy)
MM	Millimeter(s)
MOVG	Moving
MSLP	Minimum Sea-level Pressure
MSU	Microwave Sounding Unit
NARDAC	Naval Regional Data Automation Center
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NAVPACMETOCCEN	Naval Pacific Meteorology and Oceanography Center
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	Next Generation (Doppler Weather) Radar (WSR-88D)
NHC	National Hurricane Center
NIPRNET	Non-secure Internet Protocol Router Network
NM	Nautical Mile(s)
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NOGAPS or NGPS	Navy Operational or NGPS Global Atmospheric Prediction System

NPS	Naval Postgraduate School
NR	Number
NRL or NRL-MRY	Naval Research Laboratory, Monterey, CA
NORAPS or NRPS	Navy Operational Regional Atmospheric Prediction System
NSCAT	NASA Scatterometer
NSDS-E	Naval Satellite Display System-Enhanced
NWP	Northwest Pacific
NWS	National Weather Service
OBS	Observations
OLS	Operational Linescan System
ONR	Office of Naval Research
OSS	Operations Support Squadron
OSB	Ocean Sciences Branch
OTCM	One-Way (Interactive) Tropical Cyclone Model
PACAF	Pacific Air Force
PACMEDS	Pacific Meteorological Data System
PACOM	Pacific Command
PC	Personal Computer
PCN	Position Code Number
PIREP	Pilot Weather Report(s)
QBO	Quasi-Biennial Oscillation
RADOB	Radar Observation
RECON	Reconnaissance
RECR	Recurve (Forecast Aid)

RMSE	Root mean square error
ROCI	Radius of outer-most closed isobar
SAT	Satellite
SCS	South China Sea
SEC	Second(s)
SFC	Surface
SIPRNET	Secret Internet Protocol Router Network
SLP	Sea-Level Pressure
SPAWARSYSCOM	Space and Naval Warfare Systems Command, San Diego, CA
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
ST	Subtropical
STNRY	Stationary
STR	Subtropical Ridge
STRT	Straight (Forecast Aid)
STY	Super Typhoon
SWDIS	Satellite Weather Data Imaging System
TAPT	Typhoon Acceleration Prediction Technique
TC	Tropical Cyclone
TCFA	Tropical Cyclone Formation Alert
TD	Tropical Depression
TDA	Typhoon Duty Assistant
TDO	Typhoon Duty Officer
TIF	Tagged Image File format

TIROS-N	Television Infrared Observational Satellite Next Generation
TOGA	Tropical Ocean Global Atmosphere
TOVS	TIROS Operational Vertical Sounder
TS	Tropical Storm
TUTT	Tropical Upper-Tropospheric Trough
TY	Typhoon
TYAN	Typhoon Analog (Forecast Aid)
ULCC	Upper-Level Circulation Center
USAF	United States Air Force
USCINCPAC	U.S. Commander in Chief, Pacific, Honolulu, HI
USN	United States Navy
VIS	Visual
WESTPAC	Western (North) Pacific
WGTD	Weighted (Hybrid Aid)
WMO	World Meteorological Organization
WNP	Western North Pacific
WRN or WRNG	Warning(s)
WSD	Wind Speed and Direction
WSR-88D	Weather Surveillance Radar 1988 Doppler
WVTW	Water Vapor Tracked Winds
WWB	Westerly Wind Burst
WWW	World Wide Web
XT	Extratropical
XTRP	Extrapolation

Z	Zulu time (Greenwich Mean Time/Universal Coordinated Time)

APPENDIX D - PAST ANNUAL TROPICAL CYCLONE REPORTS

Copies of the past Annual Tropical Cyclone Reports for DOD agencies or contractors can be obtained through:

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Defense Technical Information Center (DTIC)
DTIC-BR (Reference & Retrieval Division)
8725 John J. Kingman Road
Suite 0940
Ft.  Belvoir, VA 22060-6218
Phone:  comm (703) 767-8274
DSN 427-9070
Fax:  comm (703) 767-9070
DSN 427-9070
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Copies for non-DOD agencies or users can be obtained from:

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National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone:  (703) 487-4650
Fax:  (703) 321-8547
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Refer to the following numbers when ordering:

Year	Acquisition Number	Year	Acquisition Number	Year	Acquisition Number
1959	AD 786147	1972	AD 768334	1985	AD A168284
1960	AD 786148	1973	AD 777093	1986	AD A184082
1961	AD 786149	1974	AD 010271	1987	AD A 191883
1962	AD 786128	1975	AD A023601	1988	AD A207206
1963	AD 786208	1976	AD A038484	1989	AD A232469
1964	AD 786209	1977	AD A055512	1990	AD A239910

Year	Acquisition Number	Year	Acquisition Number	Year	Acquisition Number
1965	AD 786210	1978	AD A070904	1991	AD A25 1952
1966	AD 785891	1979	AD A082071	1992	AD A274464
1967	AD 785344	1980	AD A094668	1993	AD A285097
1968	AD 785251	1981	AD A112002	1994	AD A301618
1969	AD 785178	1982	AD A124860	1995	AD A321611
1970	AD 785252	1983	AD A137836	1996	AD A332916
1971	AD 768333	1984	AD A153395	1997	TBD
				1998	TBD